

VEGETATION OF PACIFIC EQUATORIAL ISLANDS

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Vegetation of Pacific Equatorial Islands

By ERLING CHRISTOPHERSEN

INTRODUCTION

GEOGRAPHIC RELATIONS

This paper discusses the vegetation of Christmas, Jarvis, Fanning, Washington, Palmyra, Howland, and Baker islands, lying between Longitude 150° and 180° W and Latitude 6° N and 1° S. These islands form two groups: an eastern group consisting of Palmyra, Washington, Fanning, Christmas, and Jarvis islands; and a western group consisting of Howland and Baker islands. They are all atolls of coral origin. Christmas, Fanning, and Palmyra islands have open salt water lagoons; Washington Island has a central closed fresh-water lake; Howland, Baker, and Jarvis islands have no water bodies in their interiors. Like all coral islands they are very low, the highest part of the island, the beach crest, standing 8 to 10 feet (2.5 to 3 m.) above mean tide, with some dunes as much as 25 feet (7.5 m.) high.

The temperature of these islands is extremely uniform all through the year. Fanning Island, for example, has a mean temperature for every month in the year, during a period of 12-15 years, of $26\frac{1}{2}^{\circ}$ C (80° F), with the exception of January with a mean temperature of 26° C (79° F). The rainfall, however, is highly variable. The islands are distributed through two distinct regions, a wet belt north of the Equator including Palmyra, Washington, and Fanning islands, with Christmas Island on the border line to a dry belt immediately adjoining the Equator. The periodic migrations of trade winds have also a profound influence on the amount of precipitation. During the first half of the year the islands are exposed to the northeast trade winds which mark the rainy season. But during the second half of the year the southeast trade winds are dominant and precipitation consequently is scanty. Moreover as shown by Brooks and Braby (3) ¹ this periodicity may be interrupted by westerly winds which invariably are associated with heavy precipitation. Another factor of importance in the precipitation is the column of heated air which rises from the burning sands of the coral islands. When the conditions are favorable for precipitation over the surrounding ocean, rain is prevented from falling on the island as the relative humidity is decreased by the warm air. Clouds have been observed to approach an island, only to disappear, or to be broken up

¹ The numbers in parentheses refer to the bibliography, page 79.

immediately above, no rain being precipitated. This column of rising warm air is, of course, most pronounced over the islands with scanty vegetation, a dense vegetation cover being able to check the radiation.

The flora of the equatorial islands is not very rich, and is composed mainly of species of widespread occurrence. A total number of 60 species are divided among 48 genera, the generic coefficient having the very high value of 80, an indicator both of young age of the islands and of obstructed immigration. On the islands in the wet belt are coconut forests, most of them recently planted, but some in a natural state, also forests of *Pisonia grandis*, and forests of *Tournefortia argentea*, commonly as a fringe on the seaward side of the coconut forest. *Scaevola frutescens* and *Sida fallax*, form extensive thickets in the open. They are not found as undergrowth in the forests. Ferns, especially *Polypodium scolopendrium*, are common in the bottom layer of the forests, and the bunch grass, *Lepturus repens*, is particularly prominent in the open, unprotected localities. On the islands of the dry belt no forests are present, and the low vegetation is mainly made up of *Lepturus repens* on the beach crest and *Portulaca lutea* and *Boerhaavia tetrandra* in the interior.

SCOPE AND MATERIAL

The flora of the islands considered in this paper has been heretofore incompletely known, the only published records are the comprehensive report on Palmyra Island by Rock (23) and the scattered notes by Streets (30) on collections from Fanning, Christmas, Washington, and Palmyra islands concerning which Merrill (20) remarks:

The list of plants published by Streets was apparently not critically prepared, several names being erroneous in one respect or another, while some of the species recorded by him have not appeared in the recent collections. Attempts to locate several of the specimens in the Gray Herbarium and at the United States National Herbarium yielded negative results, the only specimen actually located being the fern recorded as *Polypodium aureum* "Sw." which proves to be *Polypodium scolopendrium* Burm. f. (*P. phymatodes* L.).

The collections made on Fanning Island in 1922 by S. C. Ball (1, 10) of Bernice P. Bishop Museum have been made available for study and through the courtesy of Professor E. D. Merrill (20), a manuscript prepared by him on the flora of Fanning and Washington islands based on collections made by W. B. Herms and H. Kirby is incorporated in this paper. The Whippoorwill Expedition of 1924 (11) was designed primarily for a scientific survey of Washington, Christmas, Jarvis, Howland, and Baker islands, but short visits were made to Fanning and Palmyra islands. (See map, fig. 1.) During the course of field work Professor H. F. Bergman gave attention chiefly to systematic collecting, while I made a study of

the ecological aspects of coral island vegetation about which information is particularly meager. Time was given to gathering data regarding temperature, evaporation, composition of soils, and delimiting plant associations with

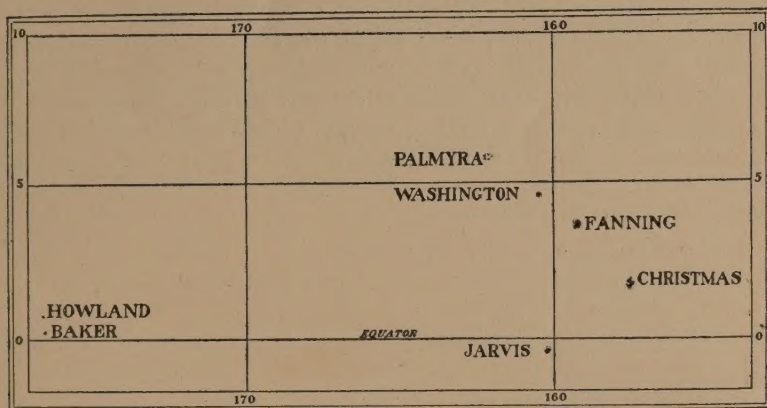


FIGURE 1.—Map showing islands visited by the Whippoorwill Expedition.

the hope that even fragmentary records may add something to the understanding of plant life on coral islands—a fascinating subject for further research.

FIELD AND LABORATORY METHODS

In the characterization of the plant associations, main emphasis has been laid on the cover degree of the component species, which was judged over areas of 1 to 100 square meters. The standards used are those of the five-graded Hult-Sernander scale (25). As most of the investigated squares were of great size, the values obtained represent little more than estimates. No values for constancy were deduced.

- V $\frac{1}{2}$ or more of surface
- IV $\frac{1}{4}$ to $\frac{1}{2}$ of surface
- III $\frac{1}{8}$ to $\frac{1}{4}$ of surface
- II $\frac{1}{16}$ to $\frac{1}{8}$ of surface
- I less than $\frac{1}{16}$ of surface

The species of an association are arranged according to the following life forms:

- TS trees and shrubs
- D dwarf shrubs
- GS grasses and sedges
- H herbs

To show the relation of the vegetation, or more especially the associations to the soil conditions under which they live, soil samples were taken from the layer of greatest root development in the soil profile, taken to the laboratory in airtight containers, and tested for reaction, contents of water, organic matter, CO_2 , and for water soluble Ca, PO_4 , and SO_4 . Carbonate was tested directly with dilute HCl; calcium phosphate and sulphate were tested in a 25 per cent water extract of the soil: calcium with an excess of ammonium oxalate, phosphate with a mixture of ammonium molybdate and sulphuric acid to which was added a drop of tin chloride and sulphate with an excess of barium chloride. All values are recorded only in terms of relative strength of reaction:

- xxx strong
- xx medium
- x weak
- O no reaction

In the lists of vascular plants the life form of each species is recorded according to the system of Raunkiaer (22), using the following symbols:

- E epiphytes
- MM mega- and meso-phanerophytes (dormant parts more than 8 m., or 27 feet, above ground)
- M microphanerophytes (dormant parts 2 to 8 m., or 7 to 27 feet, above ground)
- N nanophanerophytes (dormant parts less than 2 m., or 7 feet, above ground)
- Ch chamaephytes (dormant parts just above ground)
- H hemicryptophytes (dormant parts in the soil surface)
- G geophytes (dormant parts below ground)
- HH helophytes (dormant parts in water saturated ground) and hydrophytes (dormant parts at the bottom of water bodies)
- Th therophytes (annuals)

The frequency of each species is recorded according to a five-graded scale:

- c common
- f frequent
- o occasional
- r rare
- l local

The plants collected by the Whippoorwill Expedition form part of the herbarium of Bernice P. Bishop Museum. In the present report only the vascular plants are discussed: the mosses, lichens, and algae are being studied by others.

Acknowledgments are due to Dr. F. B. H. Brown, who has determined or passed his judgment on a number of the plants collected, and to Professor H. F. Bergman for hearty cooperation in the field and laboratory.

CHRISTMAS ISLAND

CLIMATE

The climatic data shown in Table 1 have been compiled from a report by J. English, former manager of the coconut plantation on Christmas Island, and made available through the British Meteorological Office. These records show that great variability in rainfall from year to year is characteristic of Christmas Island. While the first four months of the year had a total rainfall of 96 mm. (3.78 inches) in 1917, and 15 mm. (0.59 inches) in 1918, the same months in 1919 record a total of 1559.8 mm. (61.41 inches)—one hundred times as much. Mr. English states:

The rain appears to come in cycles. When we arrived here in May, 1916, the island appeared to be suffering from a severe drought. The wild growth of *kurima* (*Sida sp.*) was dry and dead, but in places it was so thick as to be impenetrable. Many small ponds in various parts of the island were dried up and fish were withered and dried at the bottom of them. In 1917, or rather late in 1916, the white scale appeared on the cow palms and thousands of them perished. In the latter part of 1918 the rain started in goodly quantities.

In the rainfall for 1919, January leads with a total of 2483 points (20.69 inches; 525.6 mm.). The maximum daily rainfall (on May 22) was 562 points (4.68 inches; 119 mm.) in 24 hours. January had 27 days of rain; February, 23; March, 25; April, 29; May, 18; a total of 122 rainy days out of 151 days. It is worth noting that during the rainy months the wind was northeast.

Rougier (24) states that during June 1 to 18, 1912, all the rain water tanks were overflowing and that there were fresh lakes or ponds all over the island. He also says that "The vegetation throughout the island is luxuriant. Many of the old cocoanuts on the ground were sprouting, a thing impossible without rain. . . . I had no difficulty in getting fresh water for drinking in any place. We never had to dig more than 12 inches, picking of course the lowest places."

These two contrasting descriptions of 1916 and 1912 give a clear illustration of the extreme variability in precipitation on the island, and the corresponding great changes in the aspect of the vegetation. Apparently the Whippoorwill Expedition visited the island during a dry period (August, 1924). Digging in the soil revealed no water, even at a depth of 1 meter (3 feet). At "London" the water level in the wells was about 1.5 meters (5 feet) below the surface. The plants were brown and dry with scanty development of green tissue, and no coconuts were sprouting in the plan-

TABLE 1. TEMPERATURE, PRECIPITATION, AND WIND DIRECTION,
CHRISTMAS ISLAND ^a

Month	1916	1917				1918				1919			
	Precip- itation mm.	Temp. °C		Precip- itation mm.	Wind	Temp. °C		Precip- itation mm.	Wind	Temp. °C		Precip- itation mm.	Wind
		Max.	Min.			Max.	Min.			Max.	Min.		
Jan.				0.8		39	22	2.6	E	35.5	22	525.6	NE
Feb.				5.2		39	23.5	4.6	E	34	23	399.4	NE
March				37.2		40	22	0	E	35.5	23.5	343.0	NE
April				52.8		41	23.5	7.8	E			291.8	NE
May				55.0		40	24	80.0	E	38	23.5	287.2	E
June	8.8			36.2		41	24.5	119.6	E	33.5	24	25.8	E
July	10.4			54.2		40	24.5	157.8	E	37	24	47.6	E
Aug.	1.2			1.6		40	24.5	98.0	E			17.6	
Sept.	0.2			5.2		41	24.5	80.8	SE			22.8	
Oct.	1.4	31	22	3.6		38	24.5	38.2	E	Total		1960.8	
Nov.	3.6	39	24.5	3.4	E	38	23.5	16.0	E				
Dec.	1.0	36.5	23.5	3.4	E	38	24	166.4	E				
Year				258.6		39.6	23.8	771.8					

^a In this table, which is compiled from data in English measurements, inches and points are computed to the nearest $\frac{1}{10}$ of one millimeter (approximately corresponding to $\frac{1}{100}$ of one inch, or one point), and degrees Fahrenheit to the nearest $\frac{1}{2}$ of one degree Centigrade.

tations, a sure sign of dryness. The drought was, however, not so severe as to evaporate any of the inland lakes. Precipitation was not measured, but only a few showers of short duration occurred: one heavy shower between 4 a. m. and 5 a. m. on August 2, lasting about five minutes, and a few light showers in the afternoon of August 3.

During the period July 31 to August 7, daily records of temperature, relative humidity, and evaporation were taken. (See Table 2.) From these records as from those of Table 1 a great similarity of temperature conditions throughout the year may be inferred. One day is exactly like the other.

When the relative humidity on land about 200 m. (700 feet) from the beach and on the sea just outside the beach are compared the relative humidity on land is seen to drop to a very low figure in the middle of the day, while that on the sea remains fairly uniform. See Tables 3 and 4. The dessicating effect of the land surface is thus seen to be very great and but little influenced by the surrounding ocean.

To study the evaporating power of the air on Christmas Island several atmometers were operated for a short period. These instruments were of the simple absorbing type: a porous atmometer cup with a straight glass rod connection to a 75 cc. bottle. The top of the cups had an elevation

of 30 to 40 cm. (12 to 16 inches) above ground. Four of these, with cylindrical cups, were placed as follows:

- No. 3. Exposed to sun and wind;
- No. 4. Exposed to sun, sheltered from wind;
- No. 2. Sheltered from sun, exposed to the wind (also exposed to the sun two to three hours in the early morning);
- No. 5. Sheltered from sun and wind.

TABLE 2. TEMPERATURE AND RELATIVE HUMIDITY ON LAND, CHRISTMAS ISLAND^a

1924	Temperature °C					Relative humidity, per cent		
	6 a.m.	12 Noon	6 p.m.	Max.	Min.	6 a.m.	12 Noon	6 p.m.
July 31			26					67
Aug. 1	26	31	26	32	24	79	57	75
Aug. 2	26	31	26	32	24	82	60	79
Aug. 3	26	31	26	32	25	79	66	79
Aug. 4	26	31	26	32	25	79	60	79
Aug. 5	26	31		31	25	79	66	
Aug. 6	27		26		25	75		75
Aug. 7	26				25	83		

^a See Table 1, footnote. The record for July 31, 6 p. m., to August 4, 12 m., was taken at "London"; the other records at "Paris."

TABLE NO. 3. TEMPERATURE, RELATIVE HUMIDITY, AND WIND ON BOARD THE "WHIPPOORWILL," NEAR CHRISTMAS ISLAND^a

1924	Temperature °C			Relative Humidity Per cent			Wind 8 a. m.	
	6 a.m.	12 Noon	6 p.m.	6 a.m.	12 Noon	6 p.m.	Direct.	Force
July 31			28			80		
Aug. 1	27	29	28	92	88	88	SE	2
Aug. 2	27	29	28	92	88	92	SE	1
Aug. 3	27	28	27	96	96	96	SE	2
Aug. 4	28	28	27	92	88	92	SE	2
Aug. 5	27	28	27	100	92	92	SE	2
Aug. 6	27	28	28	92	88	92	ESE	3
Aug. 7	27		96				ESE	2

^a See Table 1, footnote.

TABLE NO. 4. AVERAGE RELATIVE HUMIDITY ON LAND AND ON SHIP, CHRISTMAS ISLAND^a

Time	Temperature °C		Relative humidity per cent	
	Land	Ship	Land	Ship
6 A. M.	26.1	27.1	79	94
12 Noon	31.0	28.5	62	90
6 P. M.	26.0	27.6	76	90

^a See Table 1, footnote.

TABLE NO. 5. AVERAGE 24-HOUR EVAPORATION FOR WHITE ATMOMETER CUPS DURING 72-HOUR PERIOD, AUGUST 1-4, CHRISTMAS ISLAND

Wind	Sun			
	Exposed		Sheltered	
	No.	Evaporation cc	No.	Evaporation cc
Exposed	1	39	2	33 (partly sheltered; figure too high)
Sheltered	4	31	5	28
	6	28		

With the exception of No. 3, which ran dry after 24 hours, the atmometers were run for a period of 72 hours (August 1, noon—August 4, noon) and refilled daily to the original water level in the bottle. The average 24 hour evaporation had the following values (corrected to a standard cup of coefficient 1.00): No. 3, 41 cc; No. 4, 31 cc; No. 2, 33 cc; No. 5, 28 cc. (See Table 5.).

When a small minus correction of the figure for atmometer No. 2 is taken in consideration, it will be seen that exposure to the sun materially increases the rate of evaporation, as is to be expected. Furthermore, the effect of the wind is about equal to that of the sun.

One set (No. 1) of white and black spherical cups (radio-atmometer) was run for 48 hours (August 1, 6 p. m.—August 3, 6 p. m.) exposed to sun and wind on the beach. The average 24 hour evaporation was: white cup, 37 cc; black cup, 53 cc.

Set No. 6, in which only the white cup functioned, gave the average evaporation as 28 cc.

The ratio between day and night evaporation was determined with a cylindrical cup atmometer (No. 7) exposed to sun and wind in a *Heliotropium anomalum* association. The evaporation measured at 6 a. m. and 6 p. m. (approximate sunrise and sunset) from August 2 to August 4 showed that the ratio of night evaporation to day evaporation is about one-fourth. The figures are: 24 hours, 44cc; day (6 a. m.-6 p. m.) 35cc; night (6 p. m.-6 a. m.) 9cc.

Taking into account the slight daily and seasonal changes, the data though scanty, may be regarded as fairly representative and thus make it possible to compare these data with those for other parts of the world. A comparison of this sort is of great value, as the evaporating power of the air reflects all of the important climatic factors affecting plant growth and is closely related to the character of the vegetation. To arrive at a basis for comparison, the average 24-hour evaporation of all the white cups

exposed to sun and wind in the open, was determined. The figure thus obtained from atmometers Nos. 1, 3, and 7 is 41 cc. for 24 hours, or 287 cc. a week. Evaporation data collected by Livingston and Shreve (18) at 38 stations in the United States and Canada during the summer of 1908, show that the deserts, or the arid portions of the country, are correlated with a weekly evaporation of 300 cc. or over. Of the stations listed by Livingston and Shreve, Dickinson, North Dakota, with a weekly evaporation of 282 cc. is nearest to Christmas Island. But though the climate of Christmas Island may be referred to as semiarid, it should be borne in mind that the data are extremely scanty, and that the evaporating power of the air is not an ideal index for the characterization of the moisture relations of plants.

SOIL

The soil of the ordinary upland on Christmas Island is a light grayish brown, or light reddish brown, calcareous sand, deriving its color from the moderate admixture of organic matter. The surface layer is usually fine grained, but the lower layer consists mainly of coarse coral fragments, with very little fine sand. In general the soil has a very low water capacity, a condition that has been fatal to some of the vegetation during the drought periods.

In many places, especially on the southeastern peninsula, there is a hard pan, composed of calcium carbonate, with an average thickness of 2-3 cm. (1 inch). In some places this pan covers the surface to the absolute exclusion of all plants, in other places it is present at a deeper level. (See fig. 2.)



FIGURE 2.—Soil profile, site of former lagoon, northwestern part of Christmas Island; vegetation, scattered *Tournefortia argentea* and *Lepturus repens*: (I) crust, easily crumbled, with algal growth, 0.5 cm.; (II) light gray sand, 3 cm.; (III) hard pan, white, 1 cm.; (IV) white sand, 50 + cm.

In localities where the hard pan covers the surface, a layer of dark gray sand as much as 10 cm. (4 inches) thick, may accumulate on top of the pan. In this plants find the necessary conditions for growth.

As shown by the analyses (Table 6) the soils of Christmas Island have a uniform, weak alkaline reaction, and are very dry. The moisture content, however, increases with depth. The contents of organic matter, as indicated by loss on ignition, though not very high, is comparable to that of similar types of soils on the other islands. The very small amount of water soluble

TABLE NO. 6. ANALYSES OF SOILS, CHRISTMAS ISLAND

Sample No.	pH	Water content per cent of dry soil	Loss on ignition per cent of dry soil	CO ₂	Water soluble constituents			Color of water extract
					Ca	PO ₄	SO ₄	
1	7.9	4.1	8.6	xxx	xx	x	o	Yellow
2	8.1	7.2	5.2	xxx				
7	7.7	3.9	8.1	xxx				
8	7.8	3.7	9.4	xxx	xx	x	o	Pale yellow

1. Light grayish-brown sand with root fibers. Surface layer. Patch of pure *Boerhaavia* sp. in *Lepturus repens*-*Sida fallax* scrub, a few miles north of "London."

2. Same as 1, 40 cm. (16 inches) depth.

7. Light reddish-brown sand with root fibers. Surface layer. Pologne coconut grove.

8. Same as 7.

phosphate may in part be due to the fact that the phosphate content changes rapidly in storage, the soils were analyzed too late to gain a correct idea of the amount present in the soil at the time of collection. This statement applies also to the soils collected on the other islands visited by the *Whip-poorwill*.

On the sand flats in the northwestern part of the island, a part of a former, more extensive lagoon site, a curious polygon structure was observed (Pl. I, A). It resembles much the polygon structure described from arctic regions, but for the fact that the polygon walls are formed of small dead marine shells and are not populated by other plants than algae. As these sand fields are almost level, there is no soil flow to account for polygons. It is probable that the wind is the most important factor in their formation.

VEGETATION

THE FOREST

The most prominent forest association on Christmas Island is the coconut palm forest. Nearly all the trees now seen have been planted, but the first European visitors found coconuts growing there. Captain Cook (6, vol. 2, p. 180) states "A few cocoa-nut trees were seen in two or three

places; but in general the land had a very barren appearance. . . . On the few cocoa-trees upon the island, the number of which did not exceed thirty, very little fruit was found." On his chart of the island, Captain Cook shows coconut trees on either side of the entrance to the lagoon, where now the two settlements "Paris" and "London" are located, and he states that he planted some coconuts on the little island, Cooks Island, between the settlements. Today there are three trees on that island. It is, of course, impossible to say whether or not these early trees were in a natural state or were brought there. But the location of the trees at the entrance to the lagoon, the most natural landing place, and nowhere else, suggests former inhabitants or visitors. Besides, the heavy drought periods would kill off any trees except in the more favored inland localities which today are covered with luxuriant plantations. Soon after its discovery the number of coconut trees on Christmas Island increased, apparently planted there by stray visiting vessels. Captain Benson (2) of the whale ship *Briton*, wrecked on the east coast in 1836, speaks of several groups of coconuts in the western part of the island, the total number of trees being about 2000. His map shows coconuts in the northeastern part of the island, and some on the southern coast, planted there by himself. From about 1870 on, coconuts have been extensively planted by Mr. Greig, Mr. Lever, and Father Rougier, and today there are nearly 300,000 trees, many of which are excellent bearers. Father Rougier expressed the opinion that about 60,000 acres could be planted without improvements, thus providing for about 3,000,000 trees.

It is a remarkable fact that the trunks of the coconut trees on Christmas Island are free from lichens, while the trees on Fanning, Washington, and Palmyra islands are more or less densely covered. This is undoubtedly a reflection of the drier climate of Christmas Island.

Considering the coconut groves as artificially planted, there is only one natural forest association on the island, namely, the *Sida fallax-Tournefortia argentea* forest. *Tournefortia* is a typical beach tree, mostly scattered on the beach crest and on sand ridges in the lagoon. But in a few places inland it grows in with the *Sida* scrub to form a definite association (Pl. I, B). On the upland between lagoon and ocean about five miles north of "London," this association is well developed and has the following composition. (For explanation of symbols see p. 5):

- TS *Tournefortia argentea* III-IV
- Sida fallax* IV-V
- D *Heliotropium anomalum* I
- GS *Lepturus repens*, most places absent, IV
- H *Boerhaavia tetrandra* I
- Portulaca lutea* V

As will be seen from this list, *Tournefortia* has a low average cover degree, and the association has therefore the appearance of a park forest, near its limits even running out into savannah. The trees are not very tall, averaging 4 to 4½ meters (13 to 15 feet) in height, and have a spreading habit. Apparently *Tournefortia* is able to withstand a drier soil than does the coconut palm, which has been planted through this area without success, while thriving plantations exist nearby at a lower level.

THE SCRUB

The scrub is the most characteristic formation of Christmas Island and covers the greater part of it. There are many places where nothing else is seen. This scrub formation is made up of associations of xerophilous shrubs and grasses, and is thus a natural response to the dry climate, bearing a close resemblance to the scrub savannah of continental areas.

LEPTURUS REPENS - SIDA FALLAX SCRUB

The localities listed are: 1, dry upland near "London"; 2, dry upland near "London," zone IV in figure 3, *b*; 3, dry upland in northwestern part of island; 4, dry upland a few miles north of "London"; 5, near "London."

		1	2	3	4	5
TS	<i>Sida fallax</i>	V	IV-V	IV-V	Dead	I
D	<i>Heliotropium anomalum</i>		I	I		IV
GS	<i>Lepturus repens</i>	IV-V	III-IV	V	V	II
H	<i>Boerhaavia tetrandra</i>		II-III	I	I	I
	<i>Portulaca lutea</i>		II	II	I	I

On the northwestern part of the island near the coast *Panicum stenotaphroides* replaces *Lepturus repens*, forming a distinct facies of the association; and on the southeastern peninsula *Panicum* crowds out *Lepturus* in localities just behind the dunes, while on the dune itself and further inland *Lepturus* dominates the ground alone. While usually of low cover degree, *Portulaca lutea* appears in some localities as small patches of pure stands, but its validity as a distinct association is doubtful. *Heliotropium anomalum* may also increase its cover degree at the expense of *Sida* and *Lepturus*, thus making a gradual transition to the *Heliotropium anomalum* dwarf scrub. (See p. 18.)

In the dry upland a few miles north of "London," the *Sida* bushes are all killed off, apparently caught in one of the drought periods that occur at

intervals. Their dead straggling stems and branches are intact and show the nature of the past association. The *Lepturus* exhibits a vigorous growth, and covers the ground almost completely.

The *Lepturus repens* - *Sida fallax* scrub is one of the most common associations on the island, found everywhere in the dry upland habitats. *Sida fallax* rarely exceeds a height of 1 m. (3 feet) and usually is lower. Over wide areas on the southeastern peninsula it becomes a dwarf shrub and takes on its characteristic "espalier" habit. The development of green leaves and flowers on the *Sida* bushes was very scanty at the time of the visit of the *Whippoorwill*, but it was mostly the dried up condition of the *Lepturus* bunches that gave this association an exceedingly depauperated aspect.

The soil on which this association is found is fine sand, just beneath a bleached surface layer colored light reddish brown color by organic admixture. The layer of fine sand is usually shallow and at a depth of 30 to 40 cm. (12 to 16 inches) is replaced by a layer of coarse coral fragments. The analyses of this soil (Table 6, samples 7, 8) show that it is very dry, containing only 3.7-3.9 g. water per 100 g. dry soil. The reaction is distinctly, though not strongly, alkaline. It is a carbonate soil with a low percentage of organic matter and phosphate.

PORTULACA LUTEA-SIDA FALLAX SCRUB

Sida fallax V

Portulaca lutea III-IV

This association was observed in only one locality, on a ridge of an east-west trend about one-half mile north of camp Pologne, but here it covered large areas (Pl. I, C). Large colonies of sooty terns (*Sterna fuliginosa*) and noddy terns (*Anous stolidus*) have taken possession of this area, and it is undoubtedly due to their influence that this particular association has been developed.

While *Sida fallax* and *Portulaca lutea* are the only important species in type 2, scattered specimens of *Boerhaavia tetrandra* and *Lepturus repens* are also found.

The species *Sida fallax* is extraordinarily well developed, reaching a height of 2 m. (7 feet), and forming a dense thicket, while *Portulaca lutea* is not specially luxuriant and forms only an open growth in the field layer (average cover degree III-IV).

HELIOTROPIMUM ANOMALUM - KADUA ROMANZOFFIENSIS SCRUB

In the northern part of the southeastern peninsula *Kadua* (*Gouldia*?) *romanzoffiensis* associated with *Heliotropium anomalum* and *Lepturus repens* covers great areas (Pl. I, D). The relative importance of each

species in the association has not been determined. But *Kadua*, which appears to have a low cover degree, grows to a height of 0.5-1 m. (2-3 feet) and nowhere forming dense thickets. In the field layer *Heliotropium* is abundant, while *Lepturus* grows scattered.

The ground is extensively covered by a carbonate hard pan 2-3 cm. (1 inch) thick, and only through the cracks and breaks in this pan does the vegetation get a foothold, which accounts for the open growth. Below the hard pan is yellowish white coral sand of rather coarse texture.

SCAEVOLA FRUTESCENS SCRUB

The *Scaevola frutescens* scrub is composed of two constant species only, *Scaevola frutescens* with an average cover degree of IV, and *Heliotropium anomalum* with an average cover degree of IV-V. The bushes of *Scaevola* are of an hemispherical form with a dense display of foliage on the outside from the top down to the ground. They are built on the same principle as the coniferous "elfin wood" of alpine regions. The interior of the bush is just one tangle of stems and branches, without sign of green tissue. Most of the bushes are separated from one another, very seldom uniting to form dense thickets. They grow to an average height of 1.5-2 m. (5-7 feet), some reaching a height of 2.5 m. (8 feet). In between the *Scaevola* bushes, *Heliotropium anomalum* grows abundantly, but is probably entirely independent of their presence.

In most of the localities where the *Scaevola frutescens* association is found, the ground is covered by a carbonate hard pan, as in the *Heliotropium-Kadua* association. But in several places the hard pan is covered by a layer of sand and plant remains as much as 10 cm. (4 inches) thick in which *Scaevola* and *Heliotropium* grow without penetrating the hard pan at all.

The association occupies large areas from "Paris" southwards for about two miles and appears also in the southern part of the island between "Rapa" and "Tahiti," and in the northern part of the southeastern peninsula.

SURIANA MARITIMA SCRUB

The localities listed are: 1, depression behind beach crest on lagoon side near "London"; 2, depression behind beach crest on ocean side near "London"; 3, beach on lagoon side about five miles north of "London"; 4, elevated ridge on the sand flats in northwestern corner of lagoon. (For explanation of symbols see p. 5.)

	1	2	3	4
TS <i>Sida fallax</i>	I			
<i>Suriana maritima</i>	III-IV	III-IV	V	V
<i>Tournefortia argentea</i>		I		I
D <i>Heliotropium anomalum</i>		I		
GS <i>Lepturus repens</i>	I	I		I

The *Suriana maritima* scrub is a typical beach association, occurring on and behind the outer beach crest on both ocean and lagoon sides. It is also characteristic of elevated ridges in the lagoon, above the reach of high tide (Pl. II, A). In most places, *Suriana* forms an open growth, attaining an average height of 0.5 to 1 m. (2 to 3 feet), but in some places on the beach of the lagoon (locality 3) and at a few other places it forms a dense thicket with a height of 2 m. (7 feet).

The soil is a fine yellowish white sand with very little organic matter.

THE DWARF SCRUB

The dwarf scrub formation, the "cold" equivalent of which is the dwarf shrub heath of alpine regions, is represented on Christmas Island by only the *Heliotropium anomalum* dwarf scrub association. This, however, is widely distributed.

The only constant species in this association is *Heliotropium anomalum* with an average cover degree of III, in many places occurring in pure stands. But the following species are found in association with it: *Kadua*, *Sida fallax*, *Suriana maritima*, *Lepturus repens*, *Boerhaavia tetrandra*, and *Portulaca lutea*. None of these, however, attain an average cover degree above I.

This association is extensively distributed along the coast in the low lying areas behind the beach crest (Pl. II, B). It forms a narrow strip between the *Suriana maritima* scrub and the upland, as in the area northwest of "London" (fig. 3, b), or it develops over areas of great extent as south of "Paris" and on the south coast south of "Tahiti." It also covers the greater part of Cooks Island.

Most of the low lying areas occupied by the *Heliotropium anomalum* association are covered by coarse coral fragments, among which fine coral sand has accumulated. It is indeed a barren habitat and the scattered growth of the gray dwarf shrub imparts extreme life conditions.

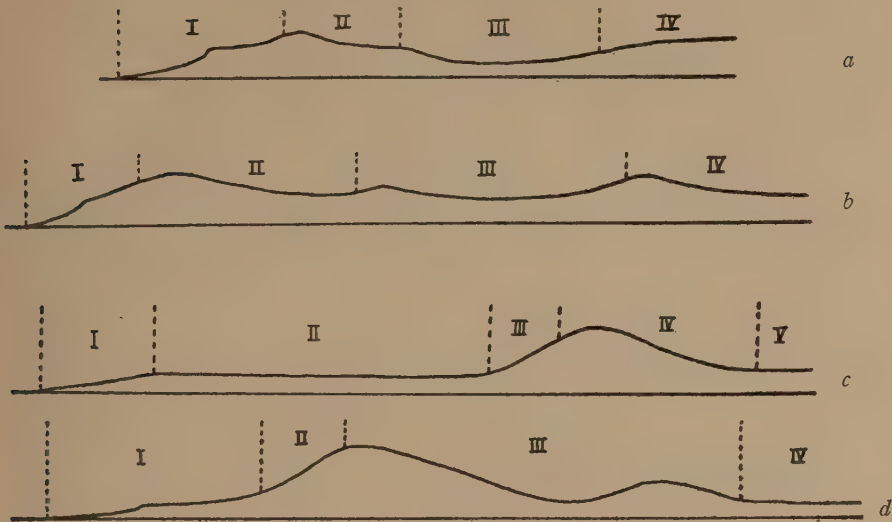


FIGURE 3.—Beach profiles, Christmas Island:

a.—Profile of lagoon beach near "London," (I) coarse pebble beach with scattered seedlings of *Tournefortia argentea*, *Scaevola frutescens*, *Suriana maritima*, and *Lepturus repens*; (II) a single row of *Tournefortia argentea* behind the crest; (III) *Suriana maritima* scrub; (IV) *Scaevola frutescens* scrub. Approximate scale: 1 : 600.

b.—Profile of the ocean beach near "London," (I) sand and pebble beach, no vegetation; (II) *Suriana maritima* scrub, fine yellowish white sand; (III) *Heliotropium anomalum* dwarf scrub, rocks and coarse pebbles with small patches of sand; (IV) *Lepturus repens*-*Sida fallax* scrub, grayish brown sand. Approximate scale: 1 : 600.

c.—Profile of ocean beach with dunes, northwestern point: (I) pebble beach, no vegetation; (II) scattered growth of *Heliotropium anomalum*, coarse coral fragments with fine yellowish white sand; (III) scattered growth of *Lepturus repens* and *Heliotropium anomalum*; (IV) dense growth of *Tournefortia argentea*, *Scaevola frutescens*, *Lepturus repens* and *Heliotropium anomalum*; (V) *Panicum stenotaphroides*-*Sida fallax* scrub. Approximate scale: 1 : 600.

d.—Profile of ocean beach with dunes, east coast: (I) sand and pebble beach, no vegetation; (II) *Scaevola frutescens* abundant, scattered specimens of *Heliotropium anomalum* and *Lepturus repens*; (III) *Lepturus repens*-*Heliotropium anomalum* association, with scattered bushes of *Scaevola frutescens* on the lee side of the first row dunes; (IV) *Heliotropium anomalum* dwarf scrub and *Lepturus repens*-*Sida fallax* scrub. Approximate scale: 1 : 700.

HERB ASSOCIATIONS

LEPTURUS REPENS-TRIBULUS CISTOIDES ASSOCIATION

In this association, *Lepturus repens* has an average cover degree of V, and dispersed all through is *Tribulus cistoides* with an average degree scarcely higher than I. Scattered specimens of *Sida fallax* and *Panicum stenotaphroides* are also found. This association was observed in only one locality about three miles north of "London," between the ocean and the

coconut grove. The reddish soil is apparently too dry for coconut palms, as the trees planted here are stunted, have yellow leaves, and bear no fruits.

LEPTURUS REPENS-HELIOTROPIUM ANOMALUM ASSOCIATION

The species *Lepturus repens* obtains an average cover degree of only III, and is associated with *Heliotropium anomalum* also at an average cover degree of III. Other species are incidental. This is the typical vegetation of the sand dunes on the east coast, it appears on the crest and lee side of the first row of dunes and all over the second row (Pl. II, C). Due to its far creeping rhizomes and copious branching, *Lepturus* is well adapted to the hazardous life on the shifting dunes, as is also *Heliotropium* with its creeping habit and much branched stems.

Scattered over these dunes bushes of *Scaevola frutescens* are found at short intervals. They are particularly abundant on the windward side together with scattered specimens of *Heliotropium anomalum* and *Lepturus repens*. Trees of *Tournefortia argentea* also appear on the dune crest, particularly on the lower dunes of the south and northwestern coasts.

In the northwestern part of the island near the lagoon, *Lepturus* covers extensive areas in pure stands at a cover degree of III-IV. The ground surface here is a carbonate hard pan in a very much broken up state.

BOERHAAVIA TETRANDRA ASSOCIATION

In several places throughout the island, *Boerhaavia tetrandra* grows over the neighboring plants and eventually kills them. The result is pure patches of *Boerhaavia* several hundred square meters in extent. Between "London" and the ocean beach, large areas are completely covered by this species.

COOKS ISLAND

On Cooks Island, in the entrance to the lagoon midway between "London" and "Paris," where Captain Cook made his observations in 1777, the following plants are growing:

<i>Lepturus repens</i>	<i>Suriana maritima</i>
<i>Cocos nucifera</i>	<i>Sida fallax</i>
<i>Boerhaavia hirsuta</i>	<i>Tournefortia argentea</i>
<i>Boerhaavia tetrandra</i>	<i>Heliotropium anomalum</i>
<i>Portulaca lutea</i>	<i>Kadua</i> (Gouldie?) <i>romanzoffensis</i>
<i>Cassipoula filiformis</i>	<i>Scaevola frutescens</i>

The entire elevated flat part of the island between beach crests is covered with *Heliotropium anomalum* at an average cover degree of III-IV, in several places covering V. and scattered in with it grow *Portulaca*, *Lepturus*,

Sida, and *Boerhaavia*. The soil is yellowish white, fine sand with negligible amounts of organic matter, mixed with coarse coral fragments.

On the beach crest is a fringe of *Tournefortia* and *Scaevola* bushes, the *Scaevola* often covered by *Cassytha* threads. A few clumps of *Tournefortia* also grow in the central part, and in their shelter, abundantly fertilized by the roosting boobies. The genus *Lepturus* reaches a luxuriant development, with broad, flat, soft green leaves, associated with *Boerhaavia hirsuta*, *B. tetrandra*, and *Portulaca*, while *Heliotropium* is entirely crowded out. Only three coconut palms are found on Cooks Island.

BEACH PROFILES

The arrangement of vegetation on Christmas Island is shown in the beach profiles figures 3, *a*, *b*, *c*, and *d*. The profile shown in figure 3, *a*, may be found in several places along the lagoon but cannot be regarded as typical. In many places, zones II and III are absent and *Scaevola* extends onto the beach. In the northwestern corner of the lagoon the different species are encountered in the following order, going from the lagoon inland:

- 1 { *Sesuvium portulacastrum*
- 1 { *Eragrostis falcata*
- 2 { *Tournefortia argentea*
- 2 { *Suriana maritima*
- 2 { *Lepturus repens*
- 3 *Heliotropium anomalum*
- 4 *Cocos nucifera*
- 5 *Sida fallax*

The succession of zones shown in figure 3, *b*, is typical for large parts of the ocean beach. Zone II is apt to disappear first, leaving only a few scattered trees of *Tournefortia argentea* on the beach crest, but the *Heliotropium* scrub is almost universally present.

The long level upper beach shown in figure 3, *c* is the equivalent of the low lying area behind the beach crest, overgrown with *Heliotropium anomalum* scrub, so commonly present on the ocean side. Here, however, the dunes give a different aspect to the profile. The crest and lee side of these dunes have a vigorous growth of *Tournefortia argentea*, which is very scarce on the more wind-exposed eastern dunes.

Only one dune along the east coast was visited, but it is probable that they all are very similar, and in a general way correspond to the profile shown in figure 3, *d*. The dunes are not continuous; from the dune represented in figure 3, *d* only one other dune could be sighted, about a mile down the coast.

VASCULAR PLANTS

For abbreviations used see p. 6.

Eragrostis amabilis (Linnaeus) Wight and Arnott.

Th. l. A few specimens at "London" and at the copra camp a few miles north. Bergman No. 15.

Eragrostis falcata (Gaudichaud) Gaudichaud.

Th. o. A pioneer plant on the sand flats in the lagoon, in places growing within the reach of high tide (Pl. II, D). Bergman No. 14.

Lepturus repens (Forster) R. Brown.

H. c. Distributed all over the island; one of the principal species in several associations (Pls. II, C; III, A). Bergman No. 1.

Panicum stenotaphroides Nees.

H. f. Widely distributed, being most abundant in the lows behind the beach crest or dunes. Agrees with Steudel's description but cannot be definitely determined. Bergman No. 7.

Cocos nucifera Linnaeus.

MM. About 300,000 trees, almost all of which have been planted. Chief plantations are at "London" and northwards, "Pologne" and "Rapa." Smaller plantations scattered.

Boerhaavia tetrandra Forster.

G. c. Distributed throughout the island, on the beach and in upland localities. It possesses a big, tuberous root; one measured 4 cm. ($1\frac{5}{8}$ inches), in diameter, with a vertical extension of more than 25' cm. (10 inches), and lateral branches equally long. The "hibernating" buds occupy the upper part of this root, thus characterizing the plant as a geophyte (root-tuber geophyte). But it seems probable that it dies back only at the most unfavorable periods, and not every year. The trailing stems reach a length of more than 2 m. (7 feet), and in many upland localities form a dense tangle to the entire exclusion of all other plants. The species has a wide range of variability and the specific identity is not clear.

The flowers vary from white to red; some stems and leaves are bright green, others are purplish red; some plants are densely pubescent, others are almost glabrous; some leaves have a velvety luster on the upper surface, others are mat; in shape the leaves vary from orbicular and emarginate through broadly ovate with obtuse apex and truncate or subcordate base, to oblong with acute apex; in size the grown-out leaf blade has a range of 0.6-4 cm. (3-19 lines) long and 0.3-3.3 cm. ($1\frac{1}{4}$ -16 lines) wide. The one distinguishing character common to all these forms is the inflorescence which is umbellate on a long peduncle, solitary in the axils of the leaves, and rarely if at all tends to take on the paniculate form so well developed in *B. paniculata*.

Richard. This paniculate inflorescence, more or less typically developed, is also found in the Polynesian *B. diffusa* Linnaeus and the West Indian *B. hirsuta* Willdenow, both referred to the pan-tropical *B. repens* Linnaeus by the Kew Index, but is not found in the material of *B. hirsuta* Linnaeus collected by the Whippoorwill Expedition. The number of stamens, which according to Guillemín (13, p. 190) is supposed to be a distinguishing character of the species, is variable and ranges between two and five.

The examination of a large amount of material from various Polynesian islands makes it certain that several distinct forms of a varietal, and perhaps even specific, rank may be delimited. For purposes of the present report all forms are referred to *Boerhaavia tetrandra* Forster and notes made on observed variations. Rock (23) determined the material collected by him on Palmyra Island as *B. tetrandra* Forster, and Setchell (26) referred his material from Rose Island, Samoa, to this species, after a comparison with a photograph of the type in the herbarium of British Museum. The specimens from Palmyra and Rose islands conform closely with some of the material collected by the Whippoorwill Expedition.

Three fairly distinct forms were observed on Christmas Island:

1. Leaf blades moderately pubescent, ciliate, ovate, obtuse to acute. Stems and petioles pubescent but not hirsute. Stems and leaves green to purplish red. Flowers red. Bergman No. 10b.

2. Leaf blades glabrate, ovate, obtuse to acute. Stems and petioles moderately pubescent. Stems and leaves green. Flowers white? (Field notes record the flowers as "pure white.") Bergman No. 9.

3. Whole plant glabrate, or stems and petioles moderately pubescent. Leaves emarginate to acute, light green to silvery on the under side. Stems and leaves green to purplish red. Flowers white? Bergman No. 11.

Boerhaavia hirsuta Linnaeus.

G. f. No authentic material of this species has been available for comparison, but on the basis of the descriptions by Sprengel (29) and by Small (28), and in view of the fact that material collected by Streets (30) has been determined by A. Gray as *B. hirsuta* Linnaeus, one of the *Boerhaavia* forms may be referred with confidence to this species. *B. hirsuta* Linnaeus has been reported from Hawaii (16) and from the Society Islands (13). These determinations, however, are regarded as synonymous with *B. diffusa* Linnaeus by Hillebrand (15) and by Castillo (4).

The nomenclature of *B. hirsuta* is unsatisfactory. Kew Index records *B. hirsuta* Linnaeus as distributed in the West Indies and North America, and regards *B. hirsuta* Willdenow as a synonym for *B. repens* Linnaeus with a pantropical distribution. Grisebach (12) lists only *B. hirsuta* Willdenow for the British West Indies, and Fawcett and Rendle (9) list only this species for Jamaica. Chapman (5) lists *B. hirsuta* Willdenow for the southeastern United States, while Small (28) lists *B. hirsuta* Linnaeus for the same area, stating that it extends its range to tropical America. If *B.*

hirsuta Linnaeus and *B. hirsuta* Willdenow should prove to be identical, then the standpoint of Kew Index in considering *B. hirsuta* Willdenow and *B. diffusa* Linnaeus as synonymous must be given up, because there is certainly a specific difference between the glabrous, diffusly branching, paniculate *B. diffusa* Linnaeus and the hirsute, slightly branching, umbellate *B. hirsuta* Linnaeus.

The whole plant is hirsute. Stems branched, trailing, green or red. Leaves ciliate, acute even acuminate, as a rule mucronate, rarely obtuse, the base acute or truncate; leaf blades 1 to 2.5 cm. by 0.5 to 1.5 cm. (5 to 12 lines by $2\frac{1}{2}$ to $7\frac{1}{2}$ lines) on petioles of one-fourth to half their length. Inflorescence umbellate on long slender sparingly hirsute peduncles which are solitary in the axils of the leaves. Flowers pink, stamens two. Fruit obovoid, 2-3 mm. (1 - $1\frac{1}{2}$ lines) long, glandular pubescent Bergman No. 10a.

Pisonia (Ceodes?) grandis R. Brown.

M. l. Only three specimens of this species are known on Christmas Island, and those are located in the northern part of the island. The trees are 6 to 7 m. (20 to 23 feet) high. No flowers or fruits were observed. Bergman No. 8.

Sesuvium portulacastrum Linnaeus.

Ch. o. Found near the water's edge in the lagoon. It is abundant on the sand flats in the northwestern corner of the lagoon, where it grows subject to partial submergence at high tide. Bergman No. 13.

Portulaca lutea Solander.

H. c. Distributed throughout the uplands, being a conspicuous element of the various *Sida fallax* associations. Bergman No. 4.

Cassytha filiformis Linnaeus.

E. f. This parasite is found here and there throughout the island, commonly on bushes of *Scaevola frutescens*, but also forming dense tangles along the ground with *Portulaca lutea* and *Heliotropium anomalum* as chief hosts. Bergman No. 34.

Lepidium owaihiense Chamisso and Schlechtendal.

Ch. r. The material collected on Christmas Island as well as on Fanning and Washington islands has been referred with much doubt to *L. owaihiense*. It seems to come very near *L. piscidium* Forster described from Society Islands, although no authentic material of this species has been available for examination. Guillemain (13, pp. 369-70) describes *L. piscidium* as herbaceous with entire leaves, but the present material has a decidedly woody base and the lower leaves are coarsely serrate, best seen in the Washington Island specimens (Bergman No. 71). A comparison with material of *L. owaihiense* from Hawaii reveals a close resemblance

throughout, with the exception of the size and shape of the silicle. The silicle of the Hawaiian plants is orbicular in shape, in some specimens broader than long (3 mm. by 4 mm.; $1\frac{1}{2}$ by 2 lines), in most specimens of equal length and width (3 to 4 mm. by 3 to 4 mm.; $1\frac{1}{2}$ to 2 lines), or slightly longer than broad (3 to 4 mm. by 3 mm. or 4 mm. by 3 to 4 mm.; $1\frac{1}{2}$ to 2 lines by $1\frac{1}{2}$ lines or 2 lines by $1\frac{1}{2}$ to 2 lines). In a few specimens the silicle reaches a size of 5 by 4 mm. ($2\frac{1}{2}$ by 2 lines), but not larger. In the material collected by the Whippoorwill Expedition, however, the silicle is obovate, and longer than that of the Hawaiian plants. The size varies somewhat for the different islands: Christmas, 5 mm. by 3 mm. ($2\frac{1}{2}$ by $1\frac{1}{2}$ lines); Fanning, 6 to 7 mm. by 3 mm. (3 to $3\frac{1}{2}$ by $1\frac{1}{2}$ lines); Washington, 6 to 7 mm. by 3 to 4 mm. (3 to $3\frac{1}{2}$ by $1\frac{1}{2}$ to 2 lines).

In the herbarium of Bernice P. Bishop Museum is a specimen collected at Tetiaroa, Society Islands, which cannot be separated from any of the material collected by the Whippoorwill Expedition. The basal leaves are coarsely serrate, and the obovate silicles are 6 to 7 mm. (3 to $3\frac{1}{2}$ lines) long and 3 mm. ($1\frac{1}{2}$ lines) wide.

It is probable that the Hawaiian and the Society Islands species run into each other, forming a continuous series of intermediate forms. Castillo (4) even regards them as synonymous.

The plant perennates by means of shoots from the upper part of the roots in the surface soil and also from the old stems above the ground. It may thus be characterized as a hemicryptophyte as well as a chamaephyte. It occurs sparingly around the settlements and in sheltered localities elsewhere on the island. Christophersen No. 48.

Tribulus cistoides Linnaeus.

Ch-N. r. Seen only in the northwestern part of the island, where it grows associated with *Lepturus repens* or scattered in the *Lepturus repens*—*Sida fallax* scrub, in dry upland localities. Bergman (Christophersen) No. 23.

Suriana maritima Linnaeus.

N. f. On the beach both on the ocean and lagoon side, in several places forming a definite zone behind the beach crest. Also abundant on most sand spits in the lagoon above high tide. Bergman No. 5.

Euphorbia hirta Linnaeus.

Th. 1. Near the settlements and copra camps. Bergman No. 19.

Phyllanthus niruri Linnaeus.

Th. 1. Specimens collected probably belong to this species, but the leaves are constantly smaller than the typical form of the species, giving the whole plant an entirely different aspect. The leaf-blades do not exceed

7 mm. ($3\frac{1}{2}$ lines) in length and average about 5 mm. ($2\frac{1}{2}$ lines) with a width of 2-3 mm. ($1-1\frac{1}{2}$ lines) on petioles of less than 1 mm. ($\frac{1}{2}$ line). Corresponding forms have also been found on Fanning, Washington and Baker islands. It was seen only near the settlements. Bergman No. 16.

***Sida cordifolia* Linnaeus.**

N. r. Observed only near "London", but probably scattered throughout the island mixed with *Sida fallax*, from which species it is separated with difficulty. Bergman No. 21.

***Sida fallax* Walpers.**

N. c. The most common shrub on the island, forming extensive thickets in all parts. It thrives in the driest upland localities, and is the principal constituent of several different associations. From a low procumbent shrub it may grow to a height of 2 m. (7 feet). Bergman No. 3.

The species *Sida diellii* A. Gray is reported by Streets (30). No material collected by the Whippoorwill Expedition can however be definitely ascribed to this species as distinct from *Sida fallax* Walpers. The species *Sida diellii* is by Hillebrand (15) regarded as a form of *Sida fallax* Walpers.

***Sida rhombifolia* Linnaeus.**

N. l. Observed only near settlements. Bergman No. 18.

***Tournefortia argentea* Linnaeus.**

M. f. On beach crests and dunes along the ocean and the lagoon all around the island; also on the small sandspits in the lagoon. In the north-western part of the island it grows in dry upland localities midway between lagoon and ocean, but elsewhere was not seen far from the beach. It does not form a continuous zone on the beach in front of the inland vegetation as at Fanning, Washington, and Palmyra islands. Bergman No. 6.

***Heliotropium anomalum* Hooker and Arnott.**

Ch. c. Common throughout the island, thriving in the driest and most exposed localities as the coral flats behind the beach crest, and on the dunes (Pls. II, B; III, B). Is a constant component of several associations. Bergman No. 2.

***Kadua romanzoffiensis* Chamisso and Schlechtendal?**

This species is known also as *Gouldia romanzoffiensis* A. Gray.

N. f. Abundant in the southern part of the island particularly near "Paris," and on the southeastern peninsula, where it is the chief constituent of a shrub association. Rare in the northern part. Bergman No. 12.

Scaevola frutescens (Miller) Krause.

N-M. c. Distributed all over the island, in upland localities as well as on the beach and dunes. It seldom forms continuous tangles, but grows in scattered semispherical bushes with dense foliage all the way down to the ground. Bergman No. 20.

Streets (30) reports *Scaevola plumiera* Vahl, as determined by A. Gray. According to Krause (17) this species is a low shrub not exceeding 1 m. (3 feet) in height with leaves 3-6 cm. ($1\frac{1}{4}$ - $2\frac{1}{2}$ inches) long, rarely longer, and 2-3.5 cm. ($\frac{3}{4}$ - $1\frac{1}{2}$ inches) wide. The material collected by the Whippoorwill Expedition, however, comes from bushes of 1.5-2.5 m. (5-8 feet) in height, and the leaves average 12 cm. (5 inches) long and 5-6 cm (2 - $2\frac{1}{2}$ inches) wide.

Vernonia cinerea Lessing.

Th. 1. At the settlements and copra camps. Bergman No. 22.

Planted at the settlements are also *Erythrina indica* Lamarck, *Hibiscus tiliaceus* Linnaeus (Bergman No. 17) and *Pandanus tectorius* Solander (Bergman No. 32).

JARVIS ISLAND

CLIMATE

No published climatic data are available for Jarvis Island, and the data obtained by the Whippoorwill Expedition are scanty. However, to judge from the nature of the soil and vegetation, the climate seems to be very dry, more so than that of Christmas Island. No trees grow on the island, and the sparse growth of herbs and low shrubs are in a partly dried up condition. The timber of the stranded barkentine *Amaranth* thrown up on the beach, was in a perfect state of preservation.

Records of temperature and relative humidity were taken August 8, 9, and 10. For these three days the temperature at 8 a. m. was 28°C.; at noon, 28°C.; at 5 p. m., 27°, 26°, and 27°C. The minimum temperature was 23°C (during a rain shower) and the maximum, 31°C. The relative humidity on land (August 10) was 76% (8 a. m.), 69% (noon), and 75% (5 p. m.); on shipboard the corresponding records are 100% (6 a. m.), 87% (noon), and 84% (6 p. m.). The wind blew from the southeast (August 8) and the east (August 9-10) with a force of 2-3.

A porous cup atmometer (p. 9) was run for a period of 24 hours exposed to sun and wind in the open, on the beach crest near the beacon (west coast). The total evaporation (corrected reading) from August 9th, 9 a. m. to August 10th, 9 a. m. was 57 cc. Compared with readings from similarly exposed atmometers on Christmas Island (cf. atmometer No. 1, Table 5) the evaporation on Jarvis Island is seen to be one and one half times as great, an indication of a much drier climate. Considering the slightly fluctuating climate of the island, this value may be regarded as close to the average, but even if it is reduced to 50 cc. to obtain a safe figure, the weekly evaporation is about equal to that for the desert station Tucson, Arizona, as given by Livingston and Shreve (18). Thus indirect and direct evidence shows, so far as the moisture relations are concerned, that Jarvis Island has a desert climate.

SOILS

Jarvis Island has long been known as a source for guano, and is at present leased by the Pacific Phosphate Company, Ltd., of London and Melbourne. The better part of the surface guano has however been taken off, and the soil at present is very shallow, and contains in most places only a small percentage of phosphate. In the low central depression inside the landward slopes of the beach crest, the soil varies from a brown or dark

brown mold with little or no sand admixture, to a light brown sandy soil, all with a high proportion of organic matter. Big heaps of this light brown soil are seen all over the island, apparently found to be too lean for profitable export. On the beach crest and its landward slopes the soil is a light grayish brown coral sand with a slight admixture of organic matter, however becoming richer where it meets the soils of the central depression. While the soil of the beach crest shows a strong reaction for CO_3 , the soils of the interior show a weak reaction or none at all.

From the analyses (Table 7) it will be seen that the sandy soils of the beach crest and its slopes, as represented by samples No. 13, 14, 16, and 22, have a lower alkaline reaction, a lower water content and a smaller loss on ignition than the moldy soils of the central depression (samples No. 12, 15, 18, and 19). It may also be noted that while the sands of the beach crest show no reaction for water soluble sulphate, the soils of the central depression are strongly influenced by the gypsum bed formed over large parts of the island. A marked difference in the phosphate content between these two types of soils is to be expected, but it does not show in the figures obtained (p. 13).

TABLE 7. ANALYSES OF SOILS, JARVIS ISLAND ^a

Sample No.	PH	Water content per cent of dry soil	Loss on ignition per cent of dry soil	CO_3	Water soluble constituents			Color of water extract
					Ca	PO_4	SO_4	
12	9.7		25.6	x				
13	8.4	7.5	5.7	xxx	xx	x	o	Clear
14	8.5	4.9	10.2	xxx	xx	x	o	Pale yellow
15	9.2	23.1	14.6	x	x	x	xxx	Pale yellow
16	8.5	6.6	9.9	xxx				
17	7.1	24.8	19.4	o				
18	9.0	35.7	19.4	o	xxx	x	xxx	Orange
19	9.7	18.8	16.0	o				
20	8.4	23.7	18.0	x				
21	5.3	8.1	18.9	o				
22	8.4	2.6	5.0	xxx				

^a For explanation of symbols see p. 6.

12. Brown guano-mixed sand. Among roots of *Sesuvium* and *Lepturus* in dense sooty tern colony, northeastern part of island.

13. Light brown sand. Vigorous growth of *Lepturus*. Lee slope of beach crest, near border to central depression, east coast.

14. Grayish brown sand with pebbles. Growth of *Portulaca*, *Lepturus*, and *Sida*. Zone IV in figure 5, a on the border to the central depression, east coast.

15. Dark reddish brown mold. Heavy growth of *Sesuvium*, some dead *Lepturus*. In central depression, near soil sample No. 14.

16. Light grayish brown, coarse sand with root fibers. Zone IV in figure 5, a east coast.

17. Yellow sand. Surface of most recently evaporated part of lagoon, north central part of island.
18. Dark brown mold. Bare patches in growth of *Sesuvium*, soil layer 2 to 5 cm. (1 to 2 inches) thick. Central part of the island.
19. Dark brown mold. Dense growth of *Sesuvium*. Central part of island.
20. Yellow salty sand mixed with plant debris. Growth of *Sesuvium*. Layers I and II of figure 4, c. North central part of island.
21. Light brown mealy sand. Layer of 30 cm. (1 foot) thickness above gypsum bed. *Lepturus* and *Sida* dead, few living bushes of *Tribulus*. Apparently worked by guano people. East of beacon. (See also Table 8, layer 1.)
22. Light gray fine sand with root fibers. Growth of *Lepturus* and *Sida*. Beach crest on northeastern coast.

TABLE No. 8. COMPOSITION OF SOIL, CENTRAL PART OF JARVIS ISLAND
(EXTRACTION WITH 25 PER CENT HCL) ^a

Layer	Ca	Mg	CO ₃	PO ₄	SO ₄	Color of extract
I	xxx		o	xxx		Orange
II	xxx		o	xx	xxx	Yellow
III	x	xxx	o	x	xxx	Yellow
IV-V	xxx	xxx	o	xxx	xx	Orange
VI	xxx	xx	xxx	xxx	x	Orange

^a For explanation of symbols see p. 6.

Soil samples 17 and 20, Table 7, collected in and near the most recently evaporated area of the former lagoon, are sandy, but show close relationship to the moldy soils of the central depression in their high water content and loss on ignition. But they have a low alkaline reaction and in spite of their sandiness they show no, or very weak, reaction for CO₃. These soils are apparently fed with water from below. On August 8 shallow pools of salty water were observed to collect on the surface, water bubbling up into them from below; on August 9 the pools were dried up. Soil sample No. 21 is unique in having an acid reaction. This dry mealy soil has nothing in common with the acid soils of the other islands visited, all in the nature of peat or phosphatic mold. No satisfactory explanation of the phenomenon is offered, but the extensive mining in the region where this soil is found, and the disturbed vegetation leads to the suggestion that it is not a natural soil but an artificial product of phosphate mining.

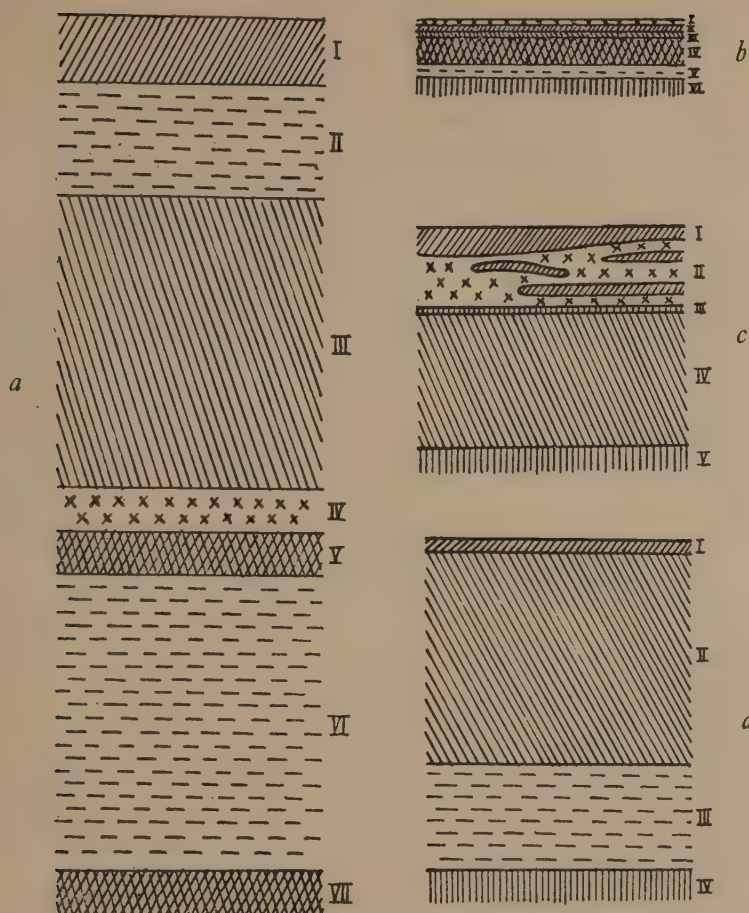


FIGURE 4.—Soil profiles, Jarvis Island.

a.—Soil profile, central part. Vegetation, scattered growth of *Tribulus cistoides* and *Lepturus repens*: (I) light brown mealy sand with root fibers (soil sample no. 21) about 10 cm.; (II) hard pan of white to light brown sand, easily crumbled, 13-21 cm.; (III) white to light brown sand, less consolidated than layer II, more compact in lower part, 41-47 cm.; (IV) crystalline material, clear or light brown, layers IV and V, 11-15 cm.; (V) hard brown material of mesh structure, mixed with crystals of layer IV, lower part unconsolidated; (VI) hard pan of white fine sand, 40-50 cm.; (VII) like layer V, consolidated, 18 cm. +.

b.—Soil profile, near low sand flat, the north central part. Vegetation, *Sesuvium portulacastrum* was growing in the vicinity, but at the particular place where the profile was cut, no higher vegetation was present: (I) white crystalline crust, layers I, II, and III, 1 cm.; (II) red (algal?) crust; (III) green algal crust; (IV) brown guano soil, partly crystalline, 3-4 cm.; (V) white hard pan, 2 cm.; (VI) white clay, moist.

c.—Soil profile in dense growth of *Sesuvium portulacastrum*, near low sand flat, north central part. Vegetation, dense growth of *Sesuvium*: (I) dark brown mold, plant debris, 0.5-4 cm.; (II) yellow sand, salty, with clear crystals, 5-8 cm.; (III) white clay, moist, 1 cm.; (IV) brown sand with plant remains, like sandy peat, 20 cm.; (V) white clay, moist.

d.—Soil profile in growth of *Sesuvium portulacastrum* and *Lepturus repens*, in the central depression, near lee slope of the beach crest, east coast. Vegetation, vigorous growth of *Sesuvium* and *Lepturus*: (I) dark brown sand, 2 cm.; (II) light brown sand, becoming lighter towards the lower part, 32 cm.; (III) white or light brown hard pan, 16 cm.; (IV) white sand.

Table 8 gives the composition of the soil in the central part of the island, where extensive mining has taken place.

In this Table, layer II represents a gypsum hard pan, extensively developed over the central part of the island, in parts replaced by a phosphatic pan. Layer III is probably of the same composition, although not consolidated into a pan. Layers IV and V are essentially phosphate beds, with some sulphate carried down from the layers above. And layer VI is a limestone bed, partly become phosphatic. It apparently does not represent the reef rock, as another phosphatic layer (fig. 4, *a*, VII) is encountered underneath.

The fertilizing effect of layers IV, V, and VII is strikingly shown by the luxuriant vegetation where these layers are exposed. In the limestone bottom of the dugouts made by the miners, plants were growing along the margins, while the middle part was absolutely devoid of any vegetation. The roots were found to follow the phosphate layer horizontally for long distances without trying to grow into the other layers.

Layers IV and V have been worked quite extensively by the phosphate miners, although by far depleted. The material was taken out by digging parallel trenches about 1 m. (3 feet) wide and piling the undesirable upper layers in between. Only a few excavations extend further down than to the limestone layer, and the phosphate layer between the trenches is still intact. The profile of the soils analyzed in Table 8 is shown in figure 4, *a*.

Near the low sand area in the north central part of the island, representing the last remains of the former lagoon, soil profiles were studied in several places. (See figure 4, *b*, *c*.) Figure 4, *d* shows the soil profile in the central depression.

The crystalline crust (fig. 4, *b*) present in and near the sand basin gives a medium reaction for carbonate, and strong reaction for Ca, PO_4 , and SO_4 . The white clay shown in both figures 4, *b*, and 4, *c* is totally soluble in HCl and is mostly composed of CaCO_3 , although showing a strong reaction for Mg. It is thus probably very fine coral or shell sand.

From the central depression towards the beach crest, the upper sand layers become progressively lighter in color, finally becoming a light grayish brown sand with very little organic matter; and the white hard pan disappears on the lee slopes of the beach crest. The vegetation also changes from an almost pure growth of *Sesuvium* to a mixture of *Lepturus*, *Portulaca*, *Boerhaavia*, and *Sida*. This rather abrupt change is undoubtedly due to the influence of the waters of the former lagoon, which reached just to this point.

In several parts of the central depression a light brown, friable phosphatic pan is encountered below a shallow layer of dark brown mold. It

is partly dissolved in 25% HCl, giving an orange red color to the extract, no, or weak, reaction for CO_3 , and strong reaction for Ca, PO_4 , and SO_4 .

VEGETATION

The vegetation of the central depression on Jarvis Island is very open and scattered. The plants are strewn over the flat as if by accident, and no definite plant associations can be distinguished. In a few places *Sesuvium* and *Boerhaavia* form dense carpets over the ground (Pl. III, C), but elsewhere no continuous vegetation is in sight.

The most vigorous species in this area is *Sesuvium portulacastrum*, being associated with the salty sand areas near the last remains of the lagoon (Table 7, sample 20), and growing in the dark brown mold (Table 7, samples 15, 18, 19) of other localities, in particular the middle and southwestern parts of the island. Near the relic lagoon most of the *Sesuvium* grows scattered (Pl. III, D). Here in one place a growth of *Lepturus repens* has been killed, leaving dead bunches flat on the ground and covered by a white felty deposit, which when partly dissolved by HCl gave the reactions: Ca—strong; PO_4 —strong; CO_3 —strong; SO_4 —medium. Microscopic examination showed this substance to consist of white filaments (*Trentepohlia* sp.?), mixed with crystalline material. The deposit may have caused the death of *Lepturus repens*. But as no similar relations were found in other parts of the island it seems more probable that the plants were killed by a profound change of the habitat, which today is a pronounced alkali flat, and certainly is not congenial to the growth of *Lepturus*. This explanation is substantiated by the fact that *Sesuvium* is entering the area, starting on the lee side of the dead *Lepturus* bunches and gradually growing over them (Pl. IV, A). The cause of this change in habitat is not known, but it is suggested that the area may have been flooded by the ground water seen to come to the surface of the relic lagoon, carrying with it sand of this salty type. The presence of alternating layers of sand and plant remains in the soil profile (fig. 4, c), also observed in many other places, is in agreement with this suggestion.

Scattered through the central depression is also found *Sida fallax*, much of it dried up and dead; *Boerhaavia tetrandra*, in places forming dense carpets; *Lepturus repens*, in general not thriving well, but exceptionally luxuriant in the sooty tern colony in the northeastern part of the island; *Portulaca lutea* and *Tribulus cistoides*.

The vegetation of the beach crest and its slopes has an entirely different aspect. It is not scattered and accidental as in the central depression, but constitutes a continuous cover and the species associate to form two fairly well defined associations.

1. LEPTURUS REPENS ASSOCIATION

TS	<i>Sida fallax</i> I
GS	<i>Lepturus repens</i> IV-V
H	<i>Boerhaavia tetrandra</i> I
	<i>Portulaca lutea</i> I

This association is primarily developed on the beach crest proper, but extends in places part way down the leeward slope (Pl. IV, *B*). The soil is a light grayish brown sand with very little organic matter. (See Table 7, sample No. 22.)

The perfect adaptation of the species of this association to the extreme conditions on the dry shifting sand is reflected in the character of their root system. The species *Sida fallax* has a long vertical tap root and long lateral roots, and the parts above ground are proportionately small. One specimen 15 cm. (6 inches) high, has a tap root of a vertical extension of more than 28 cm. (11 inches). As the name implies, *Lepturus repens* has a creeping root system, very shallow, and of great horizontal extent; while *Boerhaavia tetrandra* has a very thick, tuberous root of a vertical extension of more than 25 cm. (10 inches) and with equally long lateral branches. The species *Portulaca lutea* has a thick, long tap root and long, thin horizontal branches, or a root system wholly developed horizontally. One plant, 6 cm. (1½ inches) high above ground, was found to have a tap root extending 17 cm. (7 inches) below ground.

2. PORTULACA LUTEA ASSOCIATION

TS	<i>Sida fallax</i> I
GS	<i>Lepturus repens</i> I
H	<i>Boerhaavia tetrandra</i> I
	<i>Portulaca lutea</i> III

This association is typical of the leeward slopes of the beach crest, extending down to the vegetation of the central depression, or with a zone of *Lepturus* in between (Pl. IV, *C*). Its species are identically those of the *Lepturus repens* association, the only difference being the cover degree of *Portulaca* and *Lepturus*.

The soil is similar to that of the beach crest proper, but generally is mixed with coarse coral fragments. (See Table 7, samples 14, 16.)

BEACH PROFILES

Of the two beach profiles constructed for Jarvis Island, the profile shown in figure 5, *a* may be considered as typical for the east coast. However, the position of the secondary beach crest changes from place to place, and along the greater length of the coast two distinct fossil beaches are present, at varying distances from the outer beach crest. In the lower part

of the outer zone II, *Sida fallax* and *Boerhaavia tetrandra* may come in more abundantly, *Sida fallax* at a cover degree of III and in zone IV, *Boerhaavia tetrandra* frequently forms patches of pure growth, growing over and killing the other plants (Pl. V, C).

The profile shown in figure 5, *b* differs little from that shown in figure 5, *a*, except that it lacks the inner beach crest and has a considerably higher outer crest. The zonation and composition of the vegetation are identical.

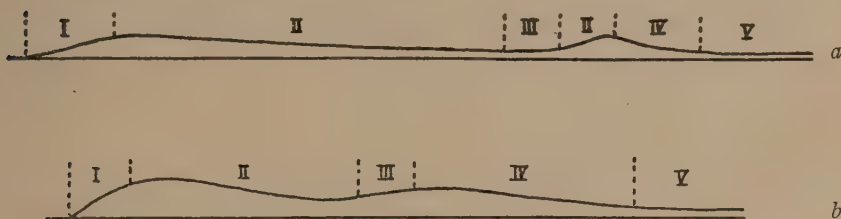


FIGURE 5.—Beach profiles, Jarvis Island

a.—Profile of the east coast: (I) pebble beach, no vegetation; (II) *Lepturus repens* association, light grayish brown sand; (III) fossil beach composed of dark gray coarse coral fragments, no vegetation (Pl. IV, D); (IV) *Portulaca lutea* association, in lower part near central depression a belt of vigorous *Lepturus repens*, light grayish brown sand with coarse coral fragments; (V) *Sesuvium portulacastrum* of central depression, dark brown sand. (Drawn from map by C. K. Wentworth.) Approximate scale: horizontal 1 : 4000; vertical 1 : 1000.

b.—Profile of north coast: (I) shingle beach, no vegetation; (II) *Lepturus repens* association, light grayish brown sand; (III) fossil beach of dark gray coral fragments, no vegetation; (IV) *Portulaca lutea* association, light grayish brown sand with coarse coral fragments; (V) *Sesuvium portulacastrum* of central depression, dark brown sand. (Drawn from map by C. K. Wentworth.) Approximate scale: horizontal 1 : 4000; vertical 1 : 1000.

On the south coast, the beach profile is very similar to that on the north coast, but on the west coast, at least in the greater part, the conditions are different. While *Lepturus repens* still dominates on the beach crest, the vegetation of the lee slope is very irregular, undoubtedly due to the use of this part of the coast as a landing place. The fossil coral pebble beach otherwise found all around the island is here broken for a great length.

VASCULAR PLANTS

Eragrostis falcata (Gaudichaud) Gaudichaud.

Th. r. Here and there in the central depression, particularly in the area that has been mined. Bergman No. 54.

Lepturus repens (Forster) R. Brown.

H. c. Very abundant on the beach crest, in many places of vigorous growth; scattered throughout the central depression. Mostly brown and dry. Bergman No. 53.

Boerhaavia tetrandra Forster.

G. c. All over the island on the beach crest as well as in the central depression. Three different forms were observed:

1. Whole plant hirsute. Leaves acute, rarely obtuse, as a rule mucronate; leaf blades 1.5-2.5 cm. by 1.0-1.5 cm. ($7\frac{1}{2}$ -12 lines by $5-7\frac{1}{2}$ lines) on short petioles. Flowers white, stamens 2-3. Peduncles very short. Comes very close to the Christmas Island form referred to *B. hirsuta* Linnaeus, but the white flowers and the fact that three stamens appear in some plants make this reference very doubtful. Bergman No. 51.

2. Leaf blades glabrous or glabrate, sparingly ciliate, obtuse to acute and mucronate, 1.5-2.0 cm. by 1.0-1.3 cm. ($7\frac{1}{2}$ -10 lines by $5-6\frac{1}{2}$ lines) on long petioles. Petioles and stems moderately pubescent. Flowers white, stamens 2. Peduncles stout. Bergman No. 52.

3. Conforms with Bergman No. 10b from Christmas Island, with the exception that the peduncles are much stouter. Bergman No. 56.

Of the three forms described, No. 2 is the most common as far as could be observed. It is the principal form on the beach crest, and occurs in dense patches in the mined area of the central depression. The other two forms are rare.

Sesuvium portulacastrum Linnaeus.

Ch. c. Abundant throughout the central depression but absent from the beach crest. Bergman No. 58.

Portulaca lutea Solander.

H. c. Throughout the central depression except on the salty sand flats near the relic lagoon; on the beach crest, and on the lee slopes of the beach crest where it is particularly abundant. Bergman No. 55.

Tribulus cistoides Linnaeus.

Ch-N. o. Scattered throughout the central depression. Bergman No. 57.

Abutilon indicum Sweet.

N. o. Scattered throughout the central depression and on the beach crest. A favorite nesting place for boobies. Bergman No. 49.

Sida fallax Walpers.

N. c. All through the island but nowhere abundant. In the central depression are many dead specimens. Bergman No. 50.

FANNING ISLAND

The exploration of Fanning Island was not included in the program of the Whippoorwill Expedition, as the flora and fauna of the island had been previously studied by scientific parties from Bernice P. Bishop Museum (7, 10). However, during two short visits of the *Whippoorwill*, opportunity was afforded for making fragmentary notes on soils and vegetation.

CLIMATE

Fanning Island climatic records, kept for a number of years by The Pacific Cable Board, have been made available through the courtesy of the Meteorological Office, London. As summarized in Table 9, these records give an excellent picture of the climate of an equatorial island. The most remarkable feature is the extremely uniform temperature conditions. Every month in the year has exactly the same normal temperature, with the exception of January with a temperature of $\frac{1}{2}^{\circ}$ C lower. The monthly mean maxima and minima are almost identical throughout the year, and the annual mean deviate only 4° C above and about 2° C below the normal temperature. It appears that the rainy season has no depressing influence on the temperature.

The force of the wind is likewise uniform. During 9 years of observation only two gales were recorded, December, 1913, and May, 1914. There is seen to be a distinct dry season during the months of August to November and a wet season during March, April and May.

The direction of the wind is closely related to the seasonal change, being mainly SE during the dry season and NE during the wet season. The average number of thunder storms for the year is 12.7; no fog has been recorded.

The normal precipitation is high, being comparable to that of the lower part of the rain forest in high islands. Thus Shreve (27) reports a rainfall of 2685-4268 mm. (105.70-168.02 inches) for the rain forest of Java, and the United States Weather Bureau gives the normal rainfall of Mt. Tantalus, on Oahu, Hawaii, as 2690 mm. (105.89 inches). Although the full benefit of all this rain cannot be enjoyed on a coral island with porous sandy soil and a comparatively low relative humidity, nevertheless the response of the vegetation is a luxuriant growth. Extensive coconut plantations are thriving in all parts of Fanning Island, and the native vegetation may develop very exacting types, as illustrated by the high dense forest of *Pisonia grandis*.

TABLE 9. TEMPERATURE, HUMIDITY, PRECIPITATION, AND WIND, FANNING ISLAND, 1903-1918^a

Month	Temperature °C					Relative humidity per cent.	Clouds. Amt. at 9 a. m. 0-10	Precipitation			Winds, direction at 9 a. m. in per cent								Mean force Beaufort scale		
	Mean	Average daily		Absolute extreme	Min.			No. of days	Average fall, mm.	Max. fall in 24 hrs. mm.	N	NE	E	SE	S	SW	W	NW		Calm	
Jan.	26.	30	24.5	35	21.5	76	6.1	284.0	13	152	1	18	22	57	1	0	0	0	0	1	3.8
Feb.	26.5	30	24.5	36	20	78	6.0	280.0	15	178	1	25	35	38	1	0	0	0	0	0	4.1
Mar.	26.5	30.5	25	36	23	79	6.2	319.8	17	196	1	36	43	20	0	0	0	0	0	0	3.9
April	26.5	30	25	36.5	21.5	81	6.7	433.8	20	196	1	34	45	17	1	0	0	1	1	1	3.7
May	26.5	30	25	36	21.5	81	6.5	373.4	19	152	2	25	44	19	4	1	0	1	4	3.1	
June	26.5	30.5	25	37	21.5	78	6.2	254.8	17	91	2	12	36	41	4	2	0	1	2	2	2.9
July	26.5	30.5	25	36.5	21	75	5.8	214.8	14	229	0	5	30	55	5	1	1	0	3	3.1	
Aug.	26.5	31	25	36.5	22	72	5.5	101.8	10	102	1	2	23	64	3	1	0	2	1	5	3.3
Sept.	26.5	31	24.5	38	20.5	69	5.3	77.0	8	79	0	3	24	64	5	1	0	2	1	3.3	
Oct.	26.5	31	25	37	21	69	5.5	96.6	9	69	1	2	15	68	6	5	1	2	0	3.2	
Nov.	26.5	31.5	25	38	23	69	5.3	73.4	8	63	0	5	28	57	1	3	1	2	3	3.5	
Dec.	26.5	30.5	24.5	36	20.5	75	6.0	223.8	2	102	1	15	31	50	0	0	0	2	1	3.6	
Year	26.5	30.5	24.8	38	20	75	5.9	2733.2	162	229	1	15	31	46	3	1	0	0	1	2	3.5
No. of yrs.	12	15	9-11			9	8	14	14	9	6-8								6-9		

^a See Table 1, foot note.

SOILS

The soil of the coconut plantations on Fanning Island is a grayish brown sand, apparently with very little organic matter. This sand forms only a shallow surface layer, being replaced a short distance below by a layer of coral fragments, interspersed with fine sand. On the beach crest the sand is lighter in color, in places even yellow-white as a consequence of a diminished percentage of organic matter.

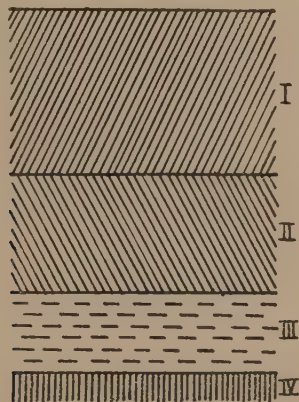


FIGURE 6.—Soil profile in coconut plantation north of Cable Station, Fanning Island. Vegetation, *Cocos nucifera*, *Lepturus repens*: (I) dark brown soil, mostly composed of coral and shell fragments of an average diameter of 1-1.5 cm., 25 cm.; (II) light brown soil, mostly composed of coral fragments of an average diameter of 0.5 cm., 18 cm.; (III) white hard pan of calcium carbonate, the depth and hardness varies considerably, 10 cm. +; (IV) white coral fragments.

In the northern part of the extensive plantation, north from the Cable Station, the soil conditions seem to be different. (See fig. 6.) In the *Pisonia* forest near the cable station the soil is dark, and in the moist environment of the forest interior, much vegetable mold accumulates.

VEGETATION

Fanning Island has generally a luxuriant vegetation, comparable to that of Palmyra Island, but less luxuriant than that of Washington Island. Coconuts were present on Fanning Island at the time of the discovery (1798) and at the present time the greater part of the island is covered with plantations. Fanning, writing in 1833 (8, p. 222), says:

On the south island, and near by a grove of cocoa-nut trees, whose fruit then lay strewn around, covering the ground from one to three feet deep, and seemed to have ripened and thus fallen for many years past, our boat's crew, having formed

themselves in a line from these to the boat, very quickly loaded her . . . we took a stroll into the interior for a few minutes, among the upland grass and groves of various kinds of trees, without being able to discover any of the valuable bread-fruit tree. At the barren spots, the birds . . . were quietly setting on their nests.

Thus coconuts have been on Fanning Island for a long time, but it does not appear that the island was extensively occupied by them. Fanning speaks of "grass and . . . various kinds of trees . . . the abundance of wood and water . . . tropical fruits, . . ."

There are several groves of *Pisonia grandis* on the northern and eastern parts of the island. In a grove near the Cable Station trees of this species attain a height of 10-15 m. (35-50 feet) and a diameter breast high of 30 cm. (12 inches) or more, their crowns forming a dense canopy admitting very little light to the forest floor. On the ground are many rotten logs covered with lichens and mosses. Lichens are also abundant on the trunks of the living trees. The soil is dark and contains a high percentage of organic matter. In the outskirts of this grove *Tournefortia argentea* is represented by many trees with heights of 10-15 m. (35-50 feet). This species is, however, more characteristic of the beach crest, at the northern inlet to the lagoon it forms low but dense forests on small islands and peninsulas.



FIGURE 7.—Profile of west coast near settlement, Fanning Island: (I) shingle beach, no vegetation; (II) scattered vegetation of *Tournefortia argentea* and *Scaevola frutescens*, coarse coral rocks; (III) dense scrub of *Scaevola frutescens*, about 2 m. in height, *Tournefortia argentea* scattered, coral rock flat, about 100 m. wide; (IV) coconut grove, with *Lepturus repens* in bottom, fine sandy soil. Approximate scale: 1 : 600.

On the west coast near the settlement *Heliotropium anomalum* is very abundant on sandy areas behind the beach crest, and southwards is a belt of densely entangled *Scaevola frutescens* scrub, about 100 m. (350 feet) wide, between the coast and the coconut groves of the inland. The beach profile shown in figure 7 is typical for the west coast from the settlement southward.

VASCULAR PLANTS

***Polypodium scolopendrium* Burmann f.**

Known also as (*P. phymatodes* Linnaeus).

H. On dead stems and stumps of coconut trees, common in the groves. Ball No. 6. Christophersen No. 19.

Merrill (20) states: "In reference to the specific name, the younger Burmann published his description of *Polypodium scolopendrium* three years earlier than the description of *Polypodium phymatodes* Linn. appeared, the actual type of the Linnean species in all probability being material transmitted to Linnaeus by Burmann."

Pandanus sp.

M. The fruits are very big and the plants may prove to belong to *P. rockii* Martelli described from Palmyra Island. Unfortunately no specimens were collected. (See Pl. V, A.)

Eragrostis amabilis (Linnaeus) Wight and Arnott.

Th. In lawns at the settlement, introduced. Merrill (20).

Lepturus repens (Forster) R. Brown.

H. Common in the coconut groves, also here and there on the beach crest. Ball No. 7. Christophersen No. 18.

Cynodon dactylon Persoon.

H. In the lawn at the settlement, introduced. Merrill (20).

Fimbristylis spathacea Roth (?).

H. The main constituent of the lawns at the settlement and at the Cable Station. Ball No. 8. Christophersen No. 17.

This species was determined by Merrill (20) from material collected by Herms and Kirby in 1924. Probably this material is identical with that of the Whippoorwill Expedition, which originally was referred to *F. cymosa* R. Brown. According to Professor Carl Skottsberg (personal communication) the material of the Whippoorwill Expedition is not identical with the Hawaiian plants called *F. cymosa* R. Brown by Hillebrand, nor with the original *F. cymosa* described by R. Brown from Australia.

Cocos nucifera Linnaeus.

MM. About 350,000 trees, mostly planted, in all parts of the island. The trunks are abundantly covered by crustose lichens.

Fleurya ruderalis (Forster) Gaudichaud.

Th. In waste places at the settlement and the Cable Station. Ball No. 10. Christophersen No. 20.

Boerhaavia tetrandra Forster.

G. Leaf blades glabrous or with glabrate veins, not ciliate, ovate, obtuse, with acute base, lighter on the under side, average size 3 cm. by 1.8 cm. (14 lines by 9 lines). Petioles and stems sparingly pubescent, some stems glabrous in the lower part, pubescent only at the nodes. Leaves and stems green to red. Inflorescence umbellate on slender peduncles.

This material conforms closely with material collected on Christmas and Washington islands (Bergman Nos. 11 and 78). Ball Nos. 5 and 16.

Pisonia grandis R. Brown(?).

MM. Forms several groves in various parts of the island. Attains a height of 15 m. (50 feet) with a diameter breast high of over 50 cm. (20 inches). No fruits nor flowers observed. Merrill (20) states: "The boobies nest in its branches in great numbers, and its distribution on isolated islands across the vast expanse of Polynesia can be accounted for through its very sticky fruits adhering to the plumage of these wide ranging birds."

Sesuvium portulacastrum Linnaeus.

Ch. On sand flats. Merrill (20).

Portulaca lutea Solander.

H. In coconut groves. Christophersen No. 22.

Cassytha filiformis Linnaeus.

E. In great abundance over trees of *Tournefortia argentea*. Merrill (20).

Lepidium owaihiense Chamisso and Schlechtendal.

Ch. Waste places around the settlement and Cable Station. Christophersen No. 16. For discussion of this species see p. 24.

Cassia occidentalis Linnaeus.

H. A weed in open places among coconut trees. Merrill (20).

Desmodium triflorum (Linnaeus) de Candolle.

Ch. Along paths in coconut groves. Merrill (20).

Suriana maritima Linnaeus.

N. Reported by Streets (30). Not collected by the Whippoorwill Expedition.

Euphorbia hirta Linnaeus.

Th. In lawns and waste places at the settlement and at the Cable Station. Ball No. 17.

Euphorbia prostrata Aiton.

Th. Near the settlement, unquestionably introduced. Merrill (20).

Phyllanthus niruri Linnaeus.

Th. The specimens collected all belong to the small leaved variety described from Christmas Island. Lawns and waste places near the settlement and the Cable Station. Ball No. 2.

Triumfetta procumbens Forster.

Ch. On the beach. Ball No. 13.

Malvastrum coromandelianum (Linnaeus) Garcke.

This plant is better known as *M. tricuspidatum* A. Gray.

Th. and Ch. In open places, introduced. Merrill (20).

Sida fallax Walpers.

N. In open places, along paths. Ball No. 15.

Ipomoea glaberrima Bojer.

Ch-M. In thickets near the sea. Merrill (20).

Tournefortia argentea Linnaeus.

M-MM. In groves inland with *Pisonia grandis*. More common along the beach crest all around the island. Reaches a height of 12-15 m. (40-50 feet), but as a rule is low and shrubby. Ball No. 1.

Cordia subcordata Lamarck.

M. Forms a thicket in the vicinity of the Cable Station. Ball No. 12.

Heliotropium anomalum Hooker and Arnott.

Ch. Common in open dry places on the beach flats and inland. Ball No. 14. Christophersen No. 21.

Scaevola frutescens (Miller) Krause.

N-M. Common along the shore and in open places inland, in many places forming dense thickets. Ball No. 3.

Erigeron albidus (Willdenow) A. Gray.

Th. In open places. Merrill (20).

Vernonia cinerea Lessing.

Th. In lawns at the settlement and the Cable Station. Ball No. 11.

Synedrella nodiflora Gaertner.

Th. Waste places near the Cable Station. Ball No. 9.

Sonchus oleraceus Linnaeus?

Th. Observed by Ball near Cable Station. Not collected.

Among the species planted at the Cable Station are the following: *Acalypha wilkesiana* Mueller of Aargan, *Araucaria* sp., *Artocarpus incisa* Linnaeus, (*A. communis* Forster?), *Calophyllum inophyllum* Linnaeus, *Carica papaya* Linnaeus, *Casuarina equisetifolia* Linnaeus, *Ficus* sp., *Hibiscus rosa sinensis* Linnaeus, *Mangifera indica* Linnaeus, *Morinda citrifolia* Linnaeus, *Musa sapientum* Linnaeus, and *Psidium guajava* Linnaeus.

Mention should also be made of *Pandanus hermsianus* Martelli, described from a drupe picked up on the beach by W. B. Herms, regarding which Martelli (19) makes the following statement: "It is highly probable that this characteristic *Pandanus* is not a native of Fanning Island, or of any of the neighboring small islands, and that the single drupe picked up on the beach originated on some larger island, and reached Fanning Island through the medium of ocean currents."

WASHINGTON ISLAND

CLIMATE

Very little is known of the climate of Washington Island. As viewed from the deck of a steamer, the island suggests a humid, wet climate. On the morning of the arrival of the *Whippoorwill* it was enveloped in a light fog, a phenomenon observed on no other island visited.

That a moist climate prevailed was made still more apparent when the luxuriant coconut forest was penetrated, and when it was discovered that the interior of the island is occupied by extensive peat bogs and a fresh water lake, unique features for coral islands.

The temperature and precipitation of Washington Island for a few months in 1922 and 1924, compiled from the records of the Fanning Island, Ltd., is shown in Table 10. For comparison the precipitation data for the corresponding months on Fanning Island is included.

Table 10 shows that no constant relation exists between the precipitation on Washington and on Fanning islands, but with the exception of May, 1922, every month shows a higher total precipitation for Washington Island, on an average exceeding that for Fanning Island about 10 per cent. No definite conclusion can be drawn from such fragmentary data, but coupled with the vegetational and physiographic evidence, it is reasonable to infer that the precipitation of Washington Island is considerably greater.

TABLE 10. TEMPERATURE AND PRECIPITATION, WASHINGTON AND FANNING ISLANDS ^a

Date	Temperature °C Washington		Precipitation Washington mm.	Precipitation Fanning mm.
	Extreme max.	Extreme min.		
1922—May	35	23	299	441
June	33	22	387	360
July	34	22	239	82
August	34	22	27	17
1924—June	30 ^b		115	94
July	30 ^b		86	58

^a See Table 1, footnote.

^b Reading taken between noon and 2 p. m.

A noteworthy feature of the records of temperature and relative humidity made by the Whippoorwill Expedition is the high values of relative humidity, and more particularly the slight drop in the noon figures. (See Table 11.) The relative humidity at Christmas Island (Table 4) besides being considerably lower, shows a much more marked decrease at noon than occurs at Washington Island.

The relative humidity on land in the open is not much lower than that on the surrounding ocean, as measured on board the ship. For the period August 14 to 18, the average records taken on land are: 6 a. m., 84; 12 noon, 78; 6 p. m., 82. The corresponding figures on board the *Whippoorwill* are 95, 92, 94.

TABLE 11. TEMPERATURE, RELATIVE HUMIDITY, AND WIND, WASHINGTON ISLAND ^a

1924	Temperature °C					Relative humidity Per cent			Wind on ship 8 a. m.	
	6 a. m.	12 noon	6 p. m.	Max.	Min.	6 a. m.	12 noon	6 p. m.	Direct	Force
Aug. 14	25	28	26	29	23	83	83	83	E	2
Aug. 15	25	28	26		23	100	80	83	E	2
Aug. 16	27	29	26		23	79	73	79	SE	2
Aug. 17	27	29	27		26	79	76	87	ESE	3
Aug. 18	27	29	26			79	76	79	E	2
Aug. 19	26				25	83			E	3

^a See Table No. 1, footnote.

A few porous cup atmometers were run for a short period in various environments. The results are as follows:

1. At the settlement, in the open exposed to sun and wind, August 18, 7 a. m., to August 19, 7 a. m. (24 hours). Total evaporation (corrected reading): 43 cc.
2. At the settlement, exposed to sun, partly sheltered from wind, August 16, 8 a. m., to August 19, 7 a. m. (71 hours). Average 24-hour evaporation (corrected reading): 33 cc.
3. In the interior of coconut grove back of the settlement, sheltered and shaded, August 16, 8 a. m., to August 19, 8 a. m. (72 hours). Average 24-hour evaporation (corrected reading): 11 cc.

While the evaporation in the open exposed to sun and wind is rather high, as compared with that of Christmas Island, the evaporation in the interior of the coconut grove is extremely low.

The dense forest cover is thus a very important factor in the moisture relations of Washington Island. It retards evaporation from the soil surface and probably decreases the evaporation from the bog and lake surface. Also, it prevents the island from becoming overheated with the consequent strong radiation which is so disadvantageous for islands with a scanty vegetation cover. The strong heat radiation from the surface of such islands as Jarvis, Baker, and Howland, all without trees and with a poorly developed plant cover, retards precipitation and consequently less rain is received than on the surrounding ocean. On the other hand, an island like Washington, where a forest cover minimizes the heat radiation, receives at least the same amount of rain as the surrounding ocean, and probably more, as the cool air of the forest may cause precipitation. The forest is, of course, a product of a moist climate already present, but after it has come into existence a reciprocal action between the forest and the climate is established, which locally modifies the original climatic conditions.

SOILS

The soils of Washington Island have a unique position among the soils of the equatorial islands visited, a reflection of a moister climate. In the coconut forest the soil is a dark brown to black mold, in many places tough and fibrous, resembling peat, of an acid reaction and high water content and composed almost exclusively of organic matter. (See Table 12, samples W5-W7.)

This soil is found throughout the relatively high areas of the forest. But in the low areas just behind the beach crest where the forest floor in several localities is frequently inundated, the soil is black, soft, and muddy, mixed with a small amount of sand, and without the tough fibrous structure found in some of the soils of the more elevated regions. (See Table 12, sample W1.) In depth the soil varies greatly, being dependent on the distance from the beach crest, as the coral rock floor slopes down towards the center of the island, while the forest floor rises. And again, towards the center of the island the layer of forest soil is replaced below by a layer of peat, increasing in depth as it approaches the lake or peat bogs. The peat of the bogs is as genuine as that found in cold temperate climates, consisting entirely of plant remains in a partly decomposed condition. It has only a slightly acid reaction of pH 5.9-6.0, which is to be expected from its calcareous environment. The water content is very high, in five samples ranging between 280 and 570 per cent of the dry weight of the peat. Most of the peat is very compact, and its surface affords a firm footing, except where it is denuded of vegetation. Upon drying it becomes very hard and solid. The color of the peat is dark brown to black. (See Table 12, samples W3-W4, W8-W10.)

In sharp contrast to these inland soils is the soil of the beach crest, which is of the same type as the beach crest soils of the other islands, a light grayish brown sand with a small amount of organic matter.

TABLE 12. ANALYSES OF SOILS, WASHINGTON ISLAND ^a

Sample No.	pH	Water content per cent of dry soil	Loss on ignition per cent of dry soil	CO ₂	Water soluble constituents			Color of water extract
					Ca	PO ₄	SO ₄	
W1	6.7	560	87	o	x	x	o	Yellow
W2	6.7	480	84	o				
W3	6.0	460	95	o	x	x	o	Pale yellow
W4		470	97	o				
W5		420	100	o				
W6		440	92	o				
W7	6.0	370	94	o				
W8	5.9	280	93	o	x	x	o	Pale yellow
W9	6.0	570	96	o				
W10		360	96	o				

^a For explanation of symbols see p. 6.

- W1. Black muddy peat. Denuded place in coconut forest, wet areas behind beach crest. Near canal east of settlement.
W2. Black peaty soil. Hummock with *Polypodium*. Near W1.
W3. Dark brown peat. Root layer in *Scirpus* growth. West bog.
W4. Dark brown peat. Root layer in *Cyrtosperma* growth. West bog.
W5. Dark brown mold. Surface layer in *Asplenium-Cocos* forest near canal between west and east bog.
W6. Dark brown mold. Near W5.
W7. Dark brown to black mold. Surface layer in coconut forest with *Pandanus*, *Asplenium*, *Polypodium*. Between south shore and east bog.
W8. Dark brown peat. Surface layer, *Scirpus* and *Cyperus polystachyus*. East bog near lake.
W9. Dark brown peat. Root layer in *Scirpus* growth. East bog near lake.
W10. Black peat from root layer in *Cyrtosperma* growth. East bog near lake.

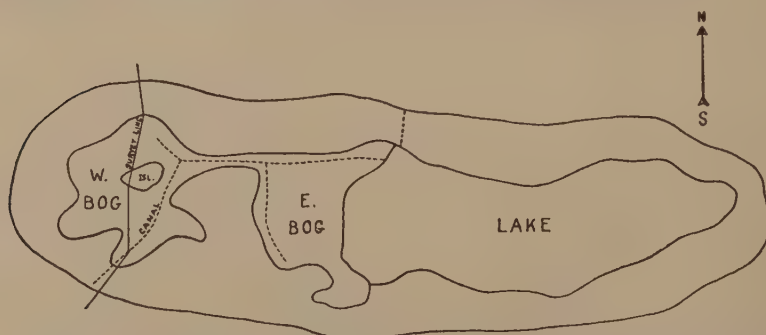


FIGURE 8.—Sketch map of Washington Island, dotted lines represent artificial canals, solid lines drawn through the western bog indicate paths used in the botanical survey. (Traced from a map made by William Greig.)

VEGETATION

The vegetation of Washington Island naturally falls in two parts: that of the central lake and bog region and that of the peripheral belt completely encircling it. (See map fig. 8.) The contrast between these two areas is very great, one being occupied mainly by a sedge meadow while the other is largely covered by a dense luxuriant coconut forest. The types of vegetation are exceptionally distinct, and several associations may be distinguished.

TOURNEFORTIA ARGENTEA FOREST

The main constituents of this forest are *Tournefortia argentea* and *Lepturus repens* (Pl. V, D). The *Tournefortia* trees usually grow to a height of 8-10 m. (25-35 feet) and may reach a diameter breast high of 70 cm. (2 1/3 feet). On account of their spreading habit their crowns form a nearly closed canopy, although their trunks grow far apart. In the field layer *Lepturus repens* comes in rather irregularly, in dense patches where the light conditions permit, otherwise scattered through the forest.

This association is found exclusively on the beach crest, forming a belt averaging 15-20 m. (50-65 feet) wide all around the island, fringing the coconut forest which follows close behind.

The soil is sand of a light grayish brown color, interspersed through coarse coral rock fragments.

ASPENIUM NIDUS-COCOS NUCIFERA FOREST

The main constituents of this forest are *Cocos nucifera* in very dense growth, and *Asplenium nidus* in great abundance on the living and dead trunks and on the ground (Pl. V, B). *Polypodium scolopendrium* and *Nephrolepis exaltata* are common throughout, and in the wetter places *Pandanus* sp. appears. This forest has the imprint of very favorable environmental conditions. It is exceedingly dense, very little light is admitted for the forest floor, and the coconut trees attain a height of 20-25 m. (65-85 feet). Dead decaying logs covered with birds-nest ferns of great size are a constant barrier to the wanderer, and the forest floor is covered by a dense entanglement of coconut seedlings, *Polypodium*, *Asplenium*, and *Nephrolepis*. Although the conditions apparently are optimum, mosses and fungi are not abundant. Only a few species of moss were observed, chiefly on decaying stumps and logs, and toadstools were rarely seen.

The forest has a distinctly virgin aspect, and although some planting has been done in late years, it is probable that as a whole it is of great age. At any rate, when the island was discovered in 1798 it had a luxuriant coconut forest. Of Fanning's original description the following lines may be of interest (8, pp. 226-27):

This was of much greater elevation than Fanning's Island, and was, moreover, covered with plants or grass, presenting to our eyes a beautiful, green, and flourishing appearance . . . there was no necessity for our making a landing here, although the trees and green foliage, among which we plainly saw the tall cocoa-nut tree, presented a very strong inducement for us . . . There can be no doubt but that at this island a vessel might obtain an abundant supply of excellent refreshments for her crew.

POLYPODIUM SCOLOPENDRIUM-PANDANUS SP. FOREST

The two most prominent species in this forest are *Pandanus sp.* of a cover degree of V, and *Polypodium scolopendrium* completely covering the forest floor. Seedlings and stray specimens of mature coconut palms are also found. This association forms a narrow belt between the coconut forest and the bog, and represents one of the intermediate steps in the encroachment of the forest upon the bog (Pl. VI, A).

CYRTOSPERMA CHAMISSONIS ASSOCIATION

A pure growth of *Cyrtosperma chamissonis*, mixed with *Polypodium scolopendrium* in the drier places, is frequently found along the edges of the bog (Pl. VI, A). The genus *Cyrtosperma* attains an average cover degree of V, and owing to the remarkably straight growth of the rhizomes the bushes appear to have been planted in rows with scrupulous regularity. They grow to an average height of 1.5 m. (5 feet) with a luxuriant display of large leaves.

The first invader into the peat bog is *Cyrtosperma*, in places mingling with the bog vegetation without apparent change in habitat.

SCIRPUS RIPARIUS ASSOCIATION

The only species in this association is *Scirpus riparius* which grows to a height of 1.5-2 m. (5-7 feet) and has an average cover degree of IV-V (Pl. VI, B).

This association covers entirely the two bog regions, and is one of the two types of vegetation that cover large parts of the island.

THE PEAT BOGS AND LAKE

The middle part of Washington Island is occupied by two peat bogs and a fresh water lake. (See map, fig. 8.) The bogs, each covering an irregularly outlined area of 80-100 hectares (about 200-250 acres), are connected by a narrow strip of a semi-boggy land. The lake is approximately 2.5 km. (1.5 miles) long and 1 km. (0.6 mile) wide.

The present bog and lake region has undoubtedly once been occupied by a salt water lagoon, as marine shells are abundant in the coral sand at the bottom of the peat layer. By the gradual emergence of the land this lagoon has been cut off from the surrounding ocean, the salt water evaporat-

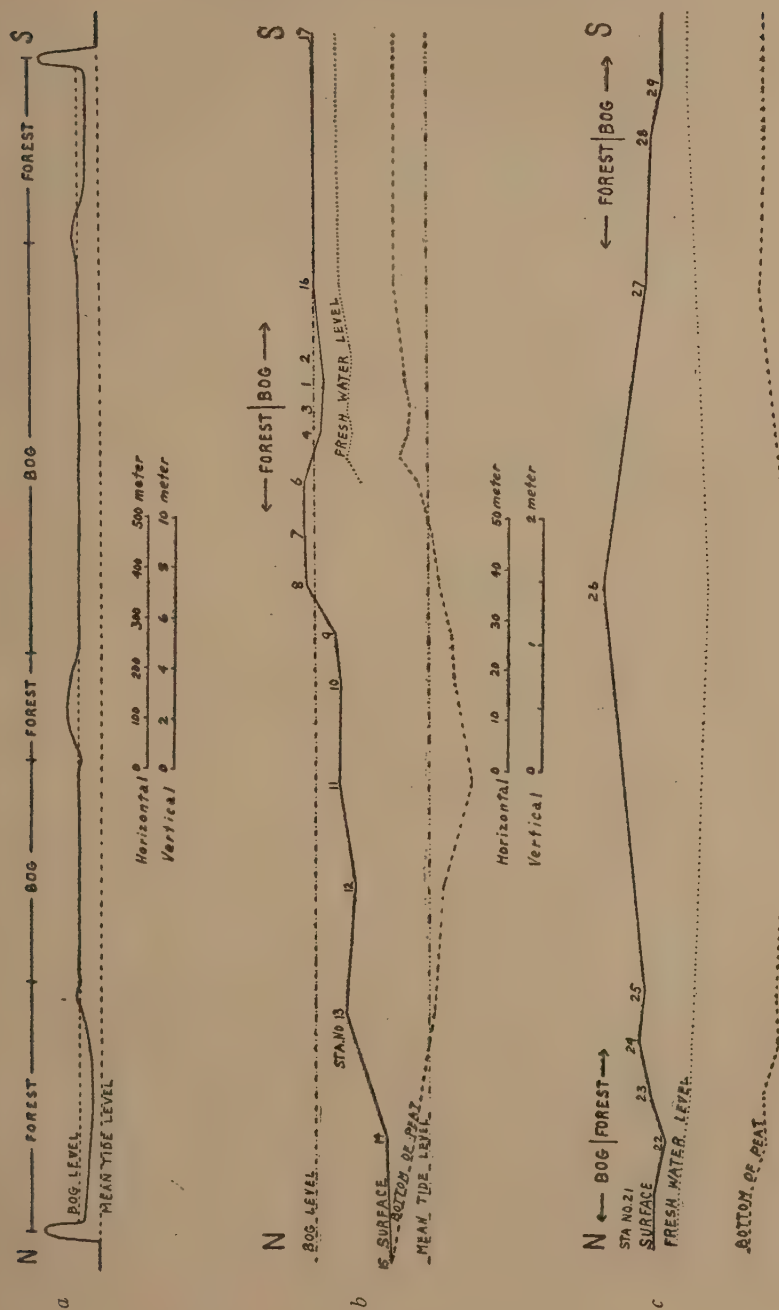


FIGURE 9.—Profiles, Washington Island: a, sketch profile across the island; b, profile at edge of forest, western bog; c, profile of islet in western bog, scale as in profile b.

ing or disappearing into the ocean through underground seepage. By abundant precipitation the salt deposits have been washed out, and the formation of a fresh water lake made possible.

Apparently the only plant to migrate into this lake is *Scirpus riparius*, which by its abundant growth has converted part of the lake into a peat bog, with a peat layer averaging 70 cm. (2 1/3 feet) in depth. At present *Scirpus riparius* is limited to the bog proper and does not grow in the remaining part of the lake. During the visit of the *Whippoorwill* the surface of the bog was entirely dry and nowhere so soft as to prevent walking upon it. But Street's reference (30) to *Scirpus riparius* as "covering the surface of the shallow fresh water lagoons" suggests that the bog may be inundated at times. At any rate, filling has come to an end and erosion has set in. Today the lake is steadily encroaching upon the coconut forest by undercutting and overthrowing the trees (Pl. VI, C). On old eastern hydrographic charts a belt of forest is shown between the lake and the bog. Nothing is left of this forest but a few scattered trees which in time will be undermined. The lake will encroach upon the bog as the bog before encroached upon it.

That the bogs formerly occupied a larger area is indicated by the peat layer underneath the surface soil of the coconut forest, at the edge of the bog and on the islet within the bog (fig. 9, b, c). The forest has thus grown out into the bog, the pioneer in this advance being *Cyrtosperma chamissonis*, which grows along the edges in pure growth or mixed with *Scirpus riparius*, but not in the middle of the bog (Pl. VI, D). Also found in this belt, but abundant in very few places, is *Cyperus polystachyus*. The next invader is *Polypodium scolopendrium*, which grows abundantly in drier places near the edge of the forest and on artificial hummocks along the canals and elsewhere. The *Pandanus* forest, with a dense floor covering of *Polypodium*, is the first tree growth to enter the bog, and forms a narrow belt in front of the advancing coconut palms and their associates: *Asplenium nidus*, *Nephrolepis exaltata*, and *Polypodium scolopendrium*. That coconut palms cannot grow directly on the bog peat is abundantly proved by extensive unsuccessful plantings in the western bog area. Coconuts planted in small artificial peat mounds either did not germinate or died shortly after germination. Only a few living seedlings are left, and the mounds are covered by *Polypodium scolopendrium*.

To gain an idea of the bog in its relation to surrounding areas, a survey line was run across the island through the western bog area and its little coconut islet (fig. 8). At suitable stations along this line, elevations were taken with a hand level, and the depth of the peat and the height of the water table measured. The results are presented in three profiles (fig. 9), which show that the bog surface lies at a higher level than the floor of the

surrounding coconut forest. The profiles in the figure also show a slightly elevated ridge at the edge of the bog separating it from the forest floor. This ridge may be a sort of natural levee resulting from overflows at the time when the drainage system was still in its natural state. Lately artificial canals have been dug for the transport of copra, and the water level may be lowered at will through cuts in the beach crest.

The following approximate elevations above mean tide were measured by Dr. C. K. Wentworth, geologist of the Whippoorwill Expedition: beach crest, 10 ft. (3 m.); low area behind beach crest, 2 ft. (60 cm.); canal, $2\frac{1}{4}$ ft. (70 cm.); peat bog, not over 3 ft. (90 cm.).

The peat layer along the line of the survey traverse is superposed on white or yellow sand, and attains a depth of 50-80 cm. ($1\frac{2}{3}$ - $2\frac{2}{3}$ feet) with an average depth of 70 cm. ($2\frac{1}{3}$ feet). In other parts of the bog a maximum depth of 112 cm. ($3\frac{2}{3}$ feet) was measured. The peat extends into the present forest region (fig. 9, *b*), gradually decreasing in thickness until it terminates at a point about 170 m. (570 feet) from the edge of the present bog. This distance is the measure of the zone covered by the forest in its advance upon the bog.

The water table lies 20-25 cm. (8-10 inches) below the bog surface, sufficiently high for the *Scirpus* roots to find the necessary moisture. But it is apparently subject to fluctuations, as over large areas *Scirpus* is entirely dead, and the peat is dry and shriveled up, showing the dead roots on the surface.

VASCULAR PLANTS

***Polypodium scolopendrium* Burmann f.**

Also known as *P. phymatodes* Linnaeus.

H. c. In the coconut forest and on the edge of the peat bogs throughout the island. Bergman No. 84.

Merrill (20) states: "This is the form recorded from Palmyra and Washington islands by Streets (30) as *Polypodium aureum* Sw., apparently *P. aureum* L. intended, the latter being a species of tropical America. Street's specimen is in the United States National Herbarium according to Mr. W. R. Maxon, and is *P. phymatodes* L.=*P. scolopendrium* Burm. f."

***Asplenium nidus* Linnaeus.**

H. and E. c. Abundant through the coconut forest, on trunks and on the ground. Bergman No. 85.

Nephrolepis exaltata Schott.

G. f. Scattered through the coconut forest. Bergman No. 97.

Psilotum triquetrum Swartz.

G. and E. r. In the coconut forest. Bergman No. 102.

Pandanus tectorius Solander(?).

M. c. In the coconut forest in wet localities and along the margin of the peat bogs. Bergman No. 119.

An exceptionally large fruit, thought to belong to *P. rockii* Martelli was collected but the specimen was lost before its specific identity was determined.

Potamogeton sp.?

HH. 1. Collected in shallow water at the east end of the lake. The material has no flowers nor fruits. The leaves are all of one kind, filiform, 3-5 cm. (1-2 inches) long. Bergman No. 103.

Eragrostis amabilis (Linnaeus) Wight and Arnott.

Th. 1. Lawns and waste places at the settlement. Bergman No. 74.

Lepturus repens (Forster) R. Brown.

H. f. Abundant on the beach crest with *Tournefortia argentea*. Bergman No. 81.

Eleusine indica (Linnaeus) Gaertner.

Th. 1. Lawns and waste places at the settlement. Bergman No. 73.

Cynodon dactylon Persoon.

H. 1. Lawns and waste places at the settlement. Bergman No. 94.

Cyperus pennatus Lamarck.

G. 1. Lawns and dry waste places at the settlement. Bergman No. 82.

Cyperus polystachyus Rottboell.

G. o. Scattered throughout the island in moist places. Bergman No. 93.

Fimbristylis spathacea Roth(?).

H. 1. Lawns and waste places at the settlement. Bergman No. 77.

Scirpus riparius Presl.

G. c. All through the peat bogs in dense growth. Bergman No. 98.

Cocos nucifera Linnaeus.

MM. c. Forms dense forests covering nearly the whole island with the exception of the peat bogs.

Cyrtosperma chamissonis (Schott) Merrill.

G. f. In wet places in the coconut forest and on the margins of the peat bogs, forming in places a dense growth. It is used by the Gilbert Island laborers as taro, but is said to be not so good. Bergman No. 118.

Merrill (20) states: "The more commonly used name for this species is *Cyrtosperma edule* Schott (1861), but *Arisacontis chamissonis* Schott, the name bringing synonym of *Cyrtosperma chamissonis*, was published four years earlier."

Fleurya ruderalis (Forster) Gaudichaud.

Th. 1. In waste places at the settlement. Bergman No. 86.

Pipturus velutinus Weddell.

N. 1. At the settlement. Bergman No. 79.

Amaranthus viridis Linnaeus.

Th. 1. In lawns and waste places at the settlement. Bergman No. 101.

Boerhaavia tetrandra Forster.

G. o. On the beach crest near the settlement. This material conforms closely with form No. 3 on Christmas Island (Bergman No. 11) and with the material from Fanning Island (Ball Nos. 5 and 16). Bergman No. 78.

Pisonia(?) grandis R. Brown.

MM. o. In scattered places on the landward slope of the beach crest. Bergman No. 99.

Cassytha filiformis Linnaeus.

E. 1. Observed only at the western end of the island, on *Scaevola*, *Polypodium*, and other plants. Bergman No. 117.

Lepidium owaihiense Chamisso and Schlechtendal.

Ch. 1. In lawns and waste places at the settlement. Bergman No. 71.

Canavalia microcarpa (de Candolle) Piper.

Ch-M. r. Creeping on the ground at the settlement, and on *Tournefortia*. Bergman No. 91.

C. glandifolia, without author name, is reported by Streets (30), but no such species has ever been described. Merrill (20) states that Streets' specimen does not exist either in the Gray Herbarium or in the United States National Herbarium. Probably Streets found the species now present on the island.

Suriana maritima Linnaeus.

N. Reported by Streets (30).

Euphorbia hirta Linnaeus.

Th. 1. In lawns and waste places at the settlement. Bergman No. 83.
Phyllanthus niruri Linnaeus.

Th. 1. In lawns and waste places at the settlement. With respect to leaf size two forms of this species were collected. One is the typical form with leaves 7-10 mm. ($3\frac{1}{2}$ -5 lines) long and 3 mm. ($1\frac{1}{2}$ lines) wide (Bergman No. 76), and the other corresponds to the small leaved forms on Christmas and Fanning islands, with leaves not exceeding 5 mm. ($2\frac{1}{2}$ lines) in length and with a width of 2-3 mm. ($1\frac{1}{2}$ lines). Bergman No. 75.

Sida rhombifolia Linnaeus.

N. 1. In waste places at the settlement. Bergman No. 87.

Malvastrum coromandelianum (Linnaeus) Garcke.

Known also as *M. tricuspidatum* A. Gray. Th and Ch. 1. In lawns and waste places at the settlement. Bergman No. 88.

Ipomoea pes-caprae (Linnaeus) Roth.

Ch. 1. On the beach at the landing place. Bergman No. 80.

Tournefortia argentea Linnaeus.

MM. f. Abundant on the beach crest all around the island. Bergman No. 72.

Cordia subcordata Lamarck.

M. 1. At the settlement. Bergman No. 89.

Scaevola frutescens (Miller) Krause.

N-M. r. At the settlement and scattered on the beach crest. Bergman No. 90.

Synedrella nodiflora Gaertner.

Th. 1. In waste places, introduced. Merrill (20).

Vernonia cinerea Lessing.

Th. 1. In lawns and waste places at the settlement. Bergman No. 95.

At the settlement the following species were found planted: *Anona squamosa* Linnaeus, *Arthocarpus incisa* Forster, *Capsicum annuum* Linnaeus var., *Carica papaya* Linnaeus, *Clerodendron inerme* (Linnaeus) Gaertner, *Hibiscus rosa sinensis* Linnaeus, *Morinda citrifolia* Linnaeus, *Musa sapientum* Linnaeus, *Plumiera acutifolia* Poiret, and *Psidium guajava* Linnaeus.

PALMYRA ISLAND

The flora and general features of the vegetation of Palmyra Island have been described by Rock (23). The present paper describes the soils of the island in their relation to the vegetation.

Compared with the other islands visited by the Whippoorwill Expedition, the moisture conditions of Palmyra are similar to those of Fanning Island as far as can be judged by the character of the vegetation and soils. Most of the islets composing Palmyra are covered by vigorous forests of coconuts and *Pisonia*, fringed by *Tournefortia* on the beach crest. The coconuts, however, are not as luxuriant as those on Washington Island.



FIGURE 10.—Map of Palmyra Island, modified from map by J. F. Rock, 1913.

The soil varies with the different islets. (See map, fig. 10.) On Home islet the inland soil is a light brown or brown coral sand, mixed with coral pebbles, dry, and most of it with a high percentage of organic matter (Table 13, samples 38, 39, 40). On the beach crest of most of the islets is found a light grayish brown sand, as a rule mixed with rootfibers, but still with a low percentage of organic matter (Table 13, samples 31, 41, 42). It supports a growth of *Tournefortia argentea*. The soil of the interior of the larger islets and some of the smaller islets is a dark brown to black mold, very moist and with a high percentage of organic matter (Table 13, samples 29, 34).

On Holei islet the soil conditions are as follows:

On the beach crests, except on the rapidly eroding southern shore, the soil is light grayish brown coral sand, similar to that of the corresponding areas on Home islet. The vegetation consists mainly of *Tournefortia argentea*.

In the interior southwestern part of the islet is a forest of *Pisonia grandis* and *Ochrosia oppositifolia* with abundant *Polypodium scolopendrium*, *Asplenium nidus*, and *Fleurya ruderalis* in the field layer. The soil is a brown to black mold with a water content in two samples of 140 and 260 per cent of the dry soil and a loss on ignition of 29 and 67 per cent respectively (Table 13, samples 33, 34). The reaction of this soil is acid, the samples having pH values of 6.5 and 5.0. This is a remarkable feature of a coral island soil. The inference is that this soil is highly phosphatic, and one of the samples shows a strong reaction for water soluble phosphate (Table 13, sample 34). The soil layer is very shallow, in some places absent, exposing the underlying coral hard pan, which has been almost completely transformed into calcium phosphate, containing approximately 20 per cent Ca and 40 per cent PO_4 , and giving a weak reaction for CO_2 . This hard pan layer is about 10-20 cm. (4-8 inches) thick, and is easily broken up. Below is a layer of yellowish white coral sand. (See fig. 11, a.)

The eastern part of Holei islet is occupied by a *Pandanus rockii-Cocos nucifera* forest and the soil conditions here are very different from those of the *Ochrosia-Pisonia* forest. The soil is dark gray sand of an alkaline reaction, moist, but much drier than the *Pisonia* soil, and with a very low percentage of organic matter, the loss on ignition being 12 per cent of the dry soil. It gives a weak reaction for water soluble phosphate (Table 13, sample 32). No hard pan is present underneath this soil in any place.

In the northwestern part of the islet is a wet depression with an open growth of coconuts and a few specimens of *Pandanus*, *Polypodium*, and *Asplenium*. The soil profile of this area is shown in figure 11, b.

Fresh water is met with a depth of 28 cm. (11 inches) below the surface. The muddy character of the surface layer and the high water level makes it probable that this depression represents the pond shown by Rock (23, p. 22). If so, the pond is intermittent, the water table rising above the surface only in wet seasons.

Islet A (fig. 10), less than 100 m. in diameter, is covered with a dense growth of tall coconuts coming down almost to the water's edge. The usual fringe of *Tournefortia* is absent, save for a few trees. In the field layer *Polypodium scolopendrium* is the only species present.

The soil of islet A is a brown to black moldy sand dispersed in gravel, of an alkaline reaction, and with a water content equal to its own dry

weight (Table 13, sample 27). The content of organic matter is rather high for a sandy soil, the loss on ignition in one sample being 32 per cent. In parts of the islet this sand is covered by a layer of dark brown to black soil of a peaty consistency and of a strongly acid reaction (Table 13, samples 26, 28). The percentage of water is very high, and the loss on ignition shows it to be pure vegetable debris. It gives a very weak reaction for

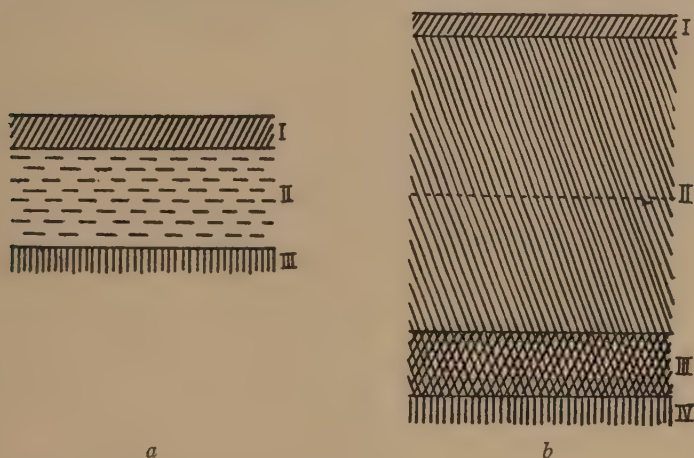


FIGURE 11.—Soil profiles, Palmyra Island.

a.—Profile in forest of *Pisonia grandis* and *Ochrosia oppositifolia*, Holei islet. Vegetation, *Ochrosia-Pisonia* forest: (I) dark brown to black mold, 0-10 cm.; (II) phosphatic hard pan, 10-20 cm.; (III) yellowish white coral sand. The root system of *Pisonia* is very shallow with a great horizontal development, and apparently does not go down into the coral sand layer to any extent.

b.—Profile in wet depression in open coconut forest, Holei islet. Vegetation, *Cocos*, *Pandanus*, *Polypodium*, *Asplenium*: (I) dark brown to black sandy mud (soil sample no. 35) 3-4 cm.; (II) dark gray sandy soil with coarse coral fragments (soil sample no. 36) 45 cm.; water table at 28 cm. below surface; (III) dark gray sandy soil with partly decomposed plant remains (soil sample no. 37) 10 cm.; (IV) yellowish white coral sand.

water soluble Ca and PO_4 . The formation of soil of this type is only possible under moist conditions, locally favored by the dense coconut forest, but undoubtedly made possible only by abundant precipitation. No hard pan is present on this islet.

Islet B (fig. 10), like islet A, is densely covered with a pure growth of tall coconut trees with *Asplenium nidus* in the field layer, and with a few *Tournefortia* trees near the water's edge. The soil is a brown moldy sand dispersed in gravel, of an alkaline reaction, moist, and with a loss on ignition in one sample of 13 per cent (Table 13, sample 30). The reaction for

water soluble phosphate is weak. On the beach crest the soil is a gray sand, dry and with a low percentage of organic matter (Table 13, sample 31). It supports a few scattered specimens of *Tournefortia*. As on islet A, no hard pan is to be found.

Papala islet (fig. 10) is covered with a pure stand of *Pisonia grandis*, with the exception of a single coconut palm placed there as by mistake. In the field layer only *Polypodium scolopendrium* is to be found, in the northern half of the islet at a cover degree of V, in the southern half only scattered.

The soil conditions of Papala islet are very different from those of coconut islets A and B. The soil is a dark brown to black peaty mold, strongly acid, moist, and almost entirely composed of organic matter (Table 13, samples 24, 25). The soil samples show a strong reaction for water soluble Ca and PO_4 . Underneath this layer of soil, which is very shallow, a hard pan is present, consisting of coral conglomerate almost completely transformed into calcium phosphate. It was entirely dissolved in 25 per cent HCl, and gave a reddish brown color to the solution. It did not react for CO_3 , and contained approximately 20 per cent Ca and 40 per cent PO_4 , thus being almost identical with the phosphatic pan present on Holei islet.

TABLE 13. ANALYSES OF SOILS, PALMYRA ISLAND

Sample No.	pH	Water content per cent of dry soil	Loss on ignition per cent of dry soil	CO_2	Water soluble constituents			Color of water extract
					Ca	PO_4	SO_4	
24	4.4	130	100	o	xx	xxx	o	Pale yellow
25		150	94	o	xxx	xxx	x	Yellow
26	4.5	250	100	o	x	x	xx	Clear
27	7.5	120	32	x				
28	4.6	200	97	o	x	x	x	Pale yellow
29		160	41	o	xx	xx	o	Clear
30	7.6	43	13	x	xx	x	x	Clear
31	8.2	13	5.6	xxx	x	x	x	Clear
32	7.6	75	12	xxx	xx	x	o	Clear
33	6.5	140	29	o	xx	x	x	Clear
34	5.0	260	67	o	xxx	xxx	x	Pale yellow
35	7.2	320	47	xx				
36	7.9	100	11	xxx				
37	7.9	140	16	xxx				
38	8.0	13	6.9	xxx				
39	7.8	50	27	xx				
40	8.0	20	10	xxx	xx	x	x	Pale yellow
41	8.1	11	6.1	xxx	xx	x	o	Pale yellow
42	8.0	7.1	5.0	xxx				
43	4.6	110	92	o	xx	xxx	xx	Pale yellow

a For explanation of symbols see p. 6.

24. Dark brown to black peaty mold. *Pisonia* forest with *Polypodium*. Papala islet.
25. Dark brown to black peaty mold. *Pisonia* forest, no field vegetation. Papala islet.
26. Dark brown to black peaty soil. Coconut forest with *Polypodium*. Islet A.
27. Black sandy mold dispersed in gravel. Coconut forest with *Polypodium*. Islet A.
28. Black peaty soil. Coconut forest with *Polypodium*. Islet A.
29. Black mold on top of phosphatic hard pan. *Ipomoea*, *Fleurya* and *Lepturus*. *Ipomoea* islet, next to Holei islet.
30. Brown sandy mold dispersed in gravel. Coconut forest with *Asplenium*. Islet B.
31. Gray sand on beach crest. *Tournefortia* scattered. Islet B.
32. Dark gray sandy soil. *Pandanus-Cocos* forest. Holei islet.
33. Dark brown to black mold on top of phosphatic hard pan. *Ochrosia-Pisonia* forest. Holei islet.
34. Dark brown to black mold on top of phosphatic hard pan. *Ochrosia-Pisonia* forest. Holei islet.
35. Black sandy mud, layer I in figure 11, b. Open *Pandanus-Cocos* forest in wet depression. Holei islet.
36. Dark grey sand mixed with coarser fragments, layer II in figure 11, b. Open *Pandanus-Cocos* forest in wet depression. Holei islet.
37. Dark gray sand with plant remains, layer III in figure 11, b. Open *Pandanus-Cocos* forest in wet depression. Holei islet.
38. Light brown sand with few coarse fragments. Coconut forest with *Tournefortia*. Home islet.
39. Brown guano-mixed coral gravel. Coconut forest with some *Tournefortia*. Home islet.
40. Brown guano, mixed coral sand and gravel. Coconut forest with some *Tournefortia*. Home islet.
41. Light grayish brown sand with rootfibers. *Tournefortia*. Beach crest, Home islet.
42. Light grayish brown sand with rootfibers. *Tournefortia*. Beach crest, Home islet.
43. Dark reddish brown mold. *Asplenium*. Home islet.

The conclusion from the analyses in Table 13 is that the forests of *Pisonia grandis* are associated with highly phosphatic soils of an acid reaction, and almost entirely composed of organic matter. The presence of a hard pan consisting of coral conglomerate more or less completely transformed into calcium phosphate, is also characteristic. The coconut forest, on the other hand, is associated with sandy non-phosphatic soils of an alkaline reaction, and with a medium or low percentage of organic matter. No hard pan is present. The *Pandanus-Cocos* forest found in wet localities is also associated with this type of soil. The fringe of *Tournefortia argentea* on the beach crest is associated with dry sand of a non-phosphatic nature and a very low percentage of organic matter. The reaction is distinctly alkaline.

BAKER AND HOWLAND ISLANDS

Baker and Howland islands, separated by a distance of only 37.5 miles, have so many features in common of climate, soils, and vegetation that they may be treated together.

CLIMATE

Not much is known of the climate of Baker and Howland islands. That they are situated in a region with very scanty precipitation, however, is abundantly illustrated by the character of their vegetation. J. D. Hague (14, p. 236) who was a resident on both islands for several months, writes:

The sky is clear and cloudless. The temperature is exceedingly even, ranging from 76° at sunrise to 88° Fahrenheit at the hottest part of the day in the shade. . . . Rain falls in light showers not infrequently. Heavy showers are rare and rainy days are unknown in my experience there. During four winter months at Baker's Island, from October 1, 1859, to February 15, 1860, rain fell twenty-three times, generally occurring in light showers or squalls, at intervals of a week or thereabouts, During these four months the least of these showers, measured by conical rain gauge, amounted to five one-thousandths of an inch on a level, and the greatest on December 19, 1859, was two hundred fifty-eight one-thousandths of an inch. . . The total amount of the four months' rain was 1.840 inches of which 0.85 inches fell in December. . . . Rain falls most frequently in the night and just before daybreak; . . . I have often observed the remarkable phenomenon of a rain squall approaching the island, and just before reaching it, separating into two parts, one of which passed by on the north, the other on the south side, the cloud having been cleft by the column of heated air rising from the white coral sands.

The breaking up of rain clouds observed by Hague and also by Ramsay (21) is undoubtedly an important factor in reducing the precipitation on these islands. The scanty vegetation of Baker and Howland islands is powerless to protect the surface from being heated; it does not prevent the consequent strong radiation, and cannot do much towards retaining what little moisture there may be in the soil. Thus these islands, situated in a naturally dry belt, receive even less precipitation than the surrounding ocean, and consequently afford a very uncongenial habitat for plant growth.

W. G. Ramsay (21) has summed up the weather conditions on Baker and Howland islands as follows:

Maximum temperature, about 94° F (34.5° C), minimum about 78° F (25.5° C); humidity comparatively low; wind, prevailing from the east, varying slightly during the daytime and backing to southwest for a short time at night; highest velocity about 15 miles an hour (6.7 meters per second) in early afternoon, falling to 3 or 4 miles an hour (1.3 or 1.8 meters per second) at night; sky partly cloudy to cloudy at night, and from eight in the morning until four in the afternoon, clear, with only small clouds floating by; barometric pressure quite constant, varying only diurnally.

The following data are extracted from the observations made by Ramsay (21) on Howland Island September 26 and 27:

Six a. m.: temperature, 28 and 26° C (82 and 79° F); relative humidity, 74 and 86; 12 noon: temperature, 32 and 34.5° C (90 and 94° F); relative humidity, 56 and 66; 4 p. m.: temperature, 30 and 30° C (86 and 86° F); relative humidity, 66 and 70. Estimated maximum temperatures, 34 and 35° C (93 and 95° F); minimum temperature, 25.5° C (78° F) both days.

These data show that the temperature conditions are very much the same as for the other islands visited by the Whippoorwill Expedition. The relative humidity is low, similar to that of Christmas Island, and strikingly lower than that of the surrounding waters as recorded on board the ship.

SOILS

Both Baker and Howland islands have been utilized as a source for guano and their more valuable deposits are practically depleted. The present soils are therefore overwhelmingly sandy, and form only a shallow layer on top of the coral conglomerate, which in places is entirely denuded.

The greater part of the interior of Baker Island is covered by a light brown sand of an alkaline reaction, dry, and with a low percentage of organic matter (Table 14, samples 61, 62, 66). In a few places the sand is darker brown, moister, has a higher percentage of organic matter (Table 14, sample 67), and supports a luxuriant growth of *Boerhaavia tetrandra*. On the beach crest is found the light grayish brown sand so characteristic of this zone on all the islands visited. It is very dry and contains a still smaller amount of organic matter than the light brown sand of the interior (Table 14, samples 63, 64).

In several places the upper part of the coral conglomerate is partly transformed into a brown phosphatic rock, giving only a weak reaction for CO₂. But no phosphatic layer similar to the one found on Jarvis Island was found. (See p. 32.) The coral conglomerate has been quarried in several places down to a depth of 2 m. (7 feet), but no apparent change in its character could be observed. In one dugout a grayish brown sandy soil had accumulated, containing a high percentage of organic matter and supporting a growth of *Fimbristylis pycnocephala* (?) (Table 14, sample 68). Another dugout, about 4 by 2.5 m. (13 by 8 feet) and 2 m. (7 feet) deep was filled with about 0.5 m. (2 feet) of water, so dirty that its salinity was not tested by tasting.

TABLE 14. ANALYSES OF SOILS, BAKER ISLAND ^a

Sample No.	pH	Water content per cent of dry soil	Loss on ignition per cent of dry soil	CO ₂	Water soluble constituents			Color of water extract
					Ca	PO ₄	SO ₄	
61	8.1	3.3	9.3	xxx	xx	x	o	Yellow
62	8.0	3.7	8.1	xxx				
63	8.1	1.9	6.4	xxx	x	x	o	Pale yellow
64	8.0	1.6	6.1	xxx	x	x	o	Pale yellow
65	8.0	27	8.1	xxx				
66	7.9	3.8	9.1	xxx				
67	7.7	7.7	18	xx	xx	xx	o	Orange
68	7.7	11	31	x				

^a For explanation of symbols see p. 6.

61. Light brown sand. *Portulaca* and *Boerhaavia*. Inland, southern part.
 62. Light brown sand. Pure *Boerhaavia*. Near 61.
 63. Light grayish brown sand. *Portulaca* and *Boerhaavia*. Beach crest, south coast.
 64. Light grayish brown sand. *Lepturus*, scattered *Portulaca* and *Boerhaavia*. Beach crest, south coast.
 65. Brown sandy soil. *Lepturus*, *Boerhaavia* scattered. Edge of small depression behind beach crest, east coast.
 66. Light brown sand. Pure *Boerhaavia*. Inland, northern part.
 67. Grayish brown sand. Heavy growth of *Boerhaavia*, and partly dead *Lepturus*. Inland, eastern part.
 68. Grayish brown sandy soil. In hole through coral conglomerate, about 30 cm. (1 foot) below surface. *Fimbristylis*. Southeastern part.

On Howland Island the soil conditions are very much the same as on Baker Island, but on Howland Island some heavy guano soil is still in place. This guano soil is associated with the groves of *Cordia subcordata*, densely populated by roosting birds. It is a brown to dark brown mold of an acid reaction, moist, and with a high percentage of organic matter (Table 15, samples 71, 73, 74, 76, 77). The samples tested give a strong reaction for water soluble calcium and phosphate, as well as for sulphate, while they do not react for carbonate at all.

A trench cut in the guano soil in the middle of *Cordia* grove No. 2 (p. 69) gave the soil profile shown in figure 12 which records the fact that *Boerhaavia*, once abundant in this place, is now completely absent. In the areas adjoining the *Cordia* grove, on soil very similar though less acid than within the grove *Boerhaavia* exhibits a luxuriant growth, but is here not exposed to the droppings of birds (Table 15, sample 75). Probably *Boerhaavia* invaded the *Cordia* grove at the time when the island was worked for guano, and most of the birds driven off. With the gradual increase of the bird population the *Boerhaavia* was killed off. In all the other *Cordia* groves

Boerhaavia is absent directly under the trees, but is abundant in open places and in the immediate surroundings, on a similar type of soil. In grove No. 5, soil samples taken in the open between the trees where *Boerhaavia* was abundant, and under the trees close by, where no field vegetation was present, consist of a brown mold, very similar, with the exception that the sample from the open was less acid than the one from under the trees

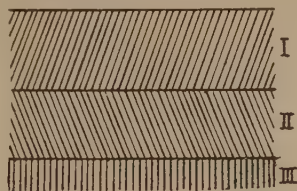


FIGURE 12.—Soil profile in a grove of *Cordia subcordata*, Howland Island. Vegetation, *Cordia subcordata*, no field vegetation: (I) dead stems of *Boerhaavia*, leaves of *Cordia*, loosely packed, 12 cm.; (II) compact tough mass of leaves and stems of *Boerhaavia*, leaves and twigs of *Cordia* and phosphatic coral fragments, like raw humus, 10 cm.; (III) dark brown mold, in the lower part becoming lighter with admixture of yellow particles, 30 cm. +.

(Table 15, samples 76, 77). As the light conditions were about the same in the two places, the bird droppings are undoubtedly responsible for the absence of *Boerhaavia* under the trees, either directly by covering the assimilating surface of the plant, or indirectly by inducing a stronger acid reaction of the soil.

The greater part of the interior of Howland Island is covered by a grayish brown or light brown sandy soil of an alkaline reaction, dry, and with a high percentage of organic matter (Table 15, samples 70, 83, 84). This soil shows a strong or medium reaction for carbonate, and one sample gave a medium reaction for water soluble calcium and phosphate. The percentage of organic matter apparently decreases with depth, as shown in samples 85 and 86 (Table 15), taken at the surface and at a depth of 30 cm. (1 foot).

On the beach crest most of the soil is a light grayish brown sand with a small percentage of organic matter (Table 15, sample 78). In some places the sand is yellowish white and has a still smaller percentage of organic matter (Table 15, samples 81, 82). The carbonate reaction is always strong, and the reaction for water soluble phosphate in two samples is weak.

TABLE 15. ANALYSES OF SOILS, HOWLAND ISLAND ^a

Sample No.	pH	Water content per cent of dry soil	Loss on ignition per cent of dry soil	CO ₂	Water soluble constituents			Color of water extract
					Ca	PO ₄	SO ₄	
70	7.9	5.0	12	xxx				Orange
71	5.3	21	23	o	xxx	xxx	xxx	
72	7.7	11	18	xx				
73	5.3	72	34	o	xxx	xxx	xxx	
74	5.2	45	15	o	xxx	xxx	x	
75	7.1	30	27	x	xxx	x	o	
76	6.6	8.2	29	o				Pale yellow
77	5.2	12	26	o				
78	7.7	1.6	8.8	xxx	xx	x	o	
79	8.3	0.7	3.8	xxx				
80	8.2	0.6	4.3	xxx				
81	8.0	0.8	5.0	xxx				Clear Yellow
82	8.0	9.6	3.2	xxx	x	x	o	
83	7.8	4.6	15	xx	xx	xx	o	
84	7.9	8.0	21	xx				
85	8.0	3.3	16	xx				
86	8.0	5.6	5.1	xxx				
87	7.5	11	13	x				

^a For explanation of symbols see p. 6.

70. Light brown fine sand with abundant root fibers. *Portulaca* and *Boerhaavia*. Central part.
71. Brown guano mold. Middle of *Cordia* grove, no bottom vegetation. Central part.
72. Brown sand. *Boerhaavia* luxuriant. Heap near *Cordia* grove, central part.
73. Dark brown guano. Upper part of layer III, figure 12. *Cordia* grove, central part.
74. Dark brown guano. Lower part of layer III, figure 12. *Cordia* grove, central part.
75. Brown guano with coarse coral fragments. *Boerhaavia* luxuriant. Depression near *Cordia* grove, central part.
76. Grayish brown coarse mold. Open places in *Cordia* grove, with pure growth of *Boerhaavia*. Central part.
77. Brown mold with coarse coral fragments. Under *Cordia* trees, no bottom vegetation. Near No. 76.
78. Light grayish brown sand. Pure *Boerhaavia*. Beach crest, east coast.
79. White coral sand. No vegetation. Just above high tide mark, west coast.
80. White coral sand with coarse coral fragments. *Boerhaavia* scattered. Belt of black coral pebbles above high tide, west coast.
81. Yellowish white coral sand on beach crest. *Boerhaavia* and *Portulaca* scattered. West coast.
82. Yellowish white coral sand. *Portulaca* and *Boerhaavia* dense. Lee side of beach crest, west coast.
83. Grayish brown sand with abundant root fibers. *Portulaca* dense, *Boerhaavia* scattered. Central part.
84. Light grayish brown sand with abundant coral fragments and root fibers. *Boerhaavia* abundant. Zone VII, figure 13, c. East coast.
85. Gray sand. *Portulaca* and *Boerhaavia*. Zone V, figure 13, b. East coast.
86. Light reddish brown sand. 30 cm. (1 foot) below surface. Same locality as soil sample No. 85.
87. Light brown sand with coarse coral fragments. Among roots of *Tribulus* bush. Northern part.

VEGETATION AND BEACH PROFILES

The vegetation of Baker and Howland islands has a very depauperate aspect. A few groves of struggling kou trees are present on Howland Island, otherwise the vegetation consists mainly of xerophilous herbs and grasses. However, the plants, such as they are, form an almost continuous cover over the islands, a condition not found on the otherwise very similar Jarvis Island.

Baker Island has 15 species of vascular plants, of which only a few are abundant. The interior is mainly covered by *Boerhaavia tetrandra* and *Portulaca lutea*, either as a mixture where each species covers approximately half the ground, or as *Boerhaavia* overgrowing *Portulaca* and almost completely conquering it. Where coral pebbles in irregular arrangement constitute part of the soil, *Boerhaavia* grows abundantly, in places with a cover degree of V. In the southern interior of the island *Lepturus repens* is common, growing pure or with *Portulaca* and *Boerhaavia* (Pl. VII, A); in the northern part, *Panicum stenotaphroides* takes its place. These grasses appeared brown and dry; only few green leaves were observed.

In the south central part of the island where conglomerate bedrock is exposed, *Fimbristylis pycnocephala* (?) is the only abundant species found, and this hardly attains a cover degree above II. It grows in dense tufts which turn coal black after the culm has died off.

On the beach crest *Lepturus* and *Panicum* are the most prominent species, vicariating for each other, or in association. In most places they form a dense growth, with *Boerhaavia* and *Portulaca* common, but of a low cover degree. The beach profile of the east coast on Baker Island is very changeable with respect to the number and relative position of the crests, but the outstanding features of the vegetation are well brought out: a *Lepturus* association on the crests, and a *Portulaca-Boerhaavia* association on the lee slopes (figure 13, a). This condition is exactly like that found on Jarvis Island. (See p. 34.)

On the beach crest of the west coast, near the landing place, several species are found not present elsewhere on Baker Island. They are *Cynodon dactylon*, *Euphorbia hirta*, *Phyllanthus niruri*, and *Ipomoea campanulata*, all except the *Ipomoea* species apparently introduced by human agencies.

On Howland Island the total number of species is five (possibly six), a very small number compared with Baker Island, only a few miles distant. But in spite of this floral discrepancy, the composition of the most prominent types of vegetation is still almost identical on the two islands. A striking difference, however, is the presence of a few groves of *Cordia subcordata* on Howland Island, altogether covering approximately 1.2 hectares (3 acres) (Pl. VII, B). On the whole, the trees seem to be on the edge of death, with green foliage only in the periphery of the grove, and usually

only on shoots from the basal part of the stem. The tops of many trees are dead, and on about one-third of the total area covered the trees are entirely dead. The trees reach a maximum height of 5 m. (17 feet), with an average height of about 3 m. (10 feet), and the lower part of the stem

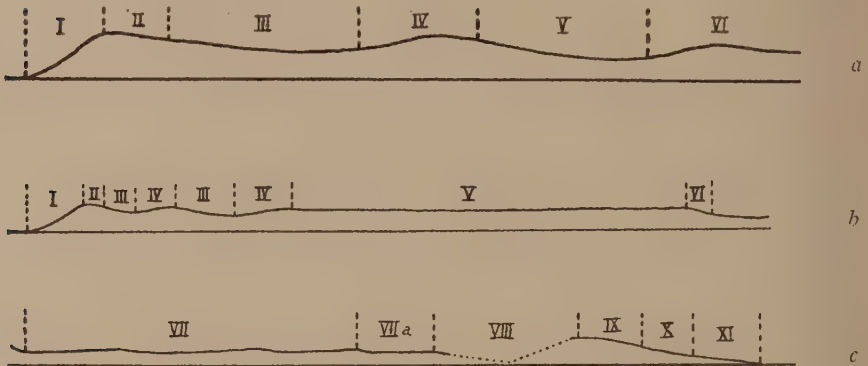


FIGURE 13.—Beach profiles, Baker and Howland islands.

a.—Profile of east coast, Baker Island: (I) shingle beach, no vegetation; (II) *Lepturus repens* IV, *Boerhaavia tetrandra* and *Portulaca lutea* scattered, light grayish brown sand; (III) *Portulaca lutea* and *Boerhaavia tetrandra*, light grayish brown sand dispersed in coarse coral fragments; (IV) *Lepturus repens* and *Panicum stenotaphroides* abundant, *Portulaca lutea* and *Boerhaavia tetrandra* scattered, light grayish brown sand; (V) *Boerhaavia tetrandra* abundant, *Portulaca lutea* scattered, light grayish brown sand; (VI) same as IV. Approximate scale: 1 : 600.

b.—Profile of east coast, Howland Island: (I) shingle beach, no vegetation (II) *Portulaca lutea* and *Boerhaavia tetrandra* scattered, coral rocks and sand; (III) coral pebble ground, no vegetation; (IV) *Portulaca lutea* and *Boerhaavia tetrandra*, light grayish brown sand; (V) *Portulaca lutea* IV, *Boerhaavia tetrandra* IV, gray and light brown sand with coral pebbles; (VI) coral pebble beach with driftwood, apparently deposited by heavy storms. Approximate scale: horizontal 1 : 2000; vertical 1 : 1000.

c.—Profile of interior and west coast, Howland Island, continuation of figure 13, b; (VII) *Boerhaavia tetrandra* IV-V. *Portulaca lutea* in places abundant, mostly scattered, coral pebble ground, pebbles 3-5 cm. in diameter, gray to black, interspersed with sand of a light grayish brown color; (VIIa) *Portulaca lutea* and *Boerhaavia tetrandra* scattered, in part coral pebbles as in zone VII, in part exposed conglomerate rock, appears to have been worked for guano; (VIII) *Portulaca lutea* and *Boerhaavia tetrandra*; (IX) *Portulaca lutea* IV, *Boerhaavia tetrandra* IV, yellowish white and gray sand (X) *Boerhaavia tetrandra* scattered, dark coral pebbles; (XI) coral pebbles with white sand, no vegetation. Approximate scale: horizontal 1 : 2000; vertical 1 : 1000.

may reach a diameter of 0.5 m. (2 feet), with branches 20 cm. (8 inches) thick. The trees are of a crooked and much branched habit. Flowers and fruits are common but not abundant. Natural reproduction from seed seems not to take place at all. All the trees are old, no seedlings were observed, and the forest floor was entirely devoid of vegetation.

Though these groves seem to be living on the verge of extinction, they have apparently been in much the same condition for at least 65 years.

Hague (14, p. 229) writes: "Near the center of the island there are one or two thickets of leafless trees or brushwood, standing eight or ten feet high and occupying an area of several acres. The tops of these trees, in which the birds roost, are apparently quite dead, but the lower parts near the roots show signs of life after every rain."

There are now five separate groves on Howland Island, all close together in the south central part. Counting from north towards south they are as follows:

No. 1. Circular in shape, approximately 200 square meters (2000 sq. feet) in extent. Maximum height of trees, 4 m. (13 feet), average height, 2.5 m. (8 feet), maximum diameter of trunks, 30 cm. (1 foot), average diameter, 8-10 cm. (3-4 inches).

No. 2. Circular in shape, approximately 200 square meters (2000 sq. feet) in extent. Maximum height of trees, 5 m. (17 feet), average height 3 m. (10 feet), maximum diameter of trunks, 15 cm. (6 inches), average diameter, 8-10 cm. (3-4 inches). Between groves No. 1 and No. 2 is a small patch of dead trees.

No. 3. Approximately 800 square meters (8500 sq. feet) in extent. Maximum height of trees, 5 m. (17 feet), average height, 2 m. (7 feet), maximum diameter of trunks, 15 cm. (6 inches), average diameter, 8-10 cm. (3-4 inches).

No. 4. Approximately 700 square meters (7500 sq. feet) in extent. Maximum height of trees, 5 m. (17 feet), average height, 2.5-3 m. (8-10 feet). Size of trunks as in grove No. 3. Groves No. 3 and No. 4 are situated in depressions and are thus partially sheltered from the dessicating effect of the wind. Although many of the tops are dead, the trees in these groves have a much more luxuriant development of foliage than those in groves No. 1 and No. 2.

No. 5. Approximately 175 by 60 m. (575 by 200 feet), thus covering an area of about 10,000 square meters (110,000 sq. feet) or five times as much as all the other groves together. The southern half of this grove consists entirely of dead trees, still intact, and with the wood in perfect preservation. The living trees form an open growth, with *Boerhaavia tetrandra* growing densely in open places. They reach a maximum height of 5 m. (17 feet), with an average height of 3 m. (10 feet), and the trunks attain a maximum diameter of 50 cm. (2 feet). Grove No. 5 is situated on a coral pebble flat; the soil is very shallow and mixed with pebbles, but is the same type of guano soil as that of the other groves.

The greater part of Howland Island inside the beach crest is covered by a mixture of *Portulaca lutea* and *Boerhaavia tetrandra* in all proportions from pure *Portulaca* to pure *Boerhaavia*, but on the whole *Portulaca* is the more abundant. Only in a few places was *Boerhaavia* seen to overgrow and kill *Portulaca*, a condition unlike that on Baker Island.

The beach crest is covered to a very small extent by the usual beach crest plant, *Lepturus repens*. In the southeastern part of the island the beach crest is covered by fine sand, to some extent shifting, and here *Lepturus repens* is abundant, growing almost pure (Pl. VII, C). Elsewhere the beach crest is occupied by *Portulaca lutea* and *Boerhaavia tetrandra* in about equal proportions, with a combined average cover degree of V. The profile of the east coast is shown in figure 13, *b*, and the continuation of the profile across the island to the west coast in figure 13, *c*.

VASCULAR PLANTS, BAKER ISLAND

Eragrostis falcata (Gaudichaud) Gaudichaud.

Th. r. Only three specimens seen on the beach, in the southern part of island. Christophersen No. 30.

Lepturus repens (Forster) R. Brown.

H. c. Abundant on the beach crest, also abundant in places throughout the interior. Christophersen No. 31.

Cynodon dactylon Persoon.

H. l. On the beach crest near the landing on west coast. Christophersen No. 24.

Panicum stenotaphroides Ness (?).

H. c. On the beach crest abundant, also abundant in parts of the interior, particularly the northern half of the island. Christophersen No. 38.

Fimbristylis pycnocephala Hillebrand(?).

H. o. In the interior, in pockets on exposed coral conglomerate. Christophersen No. 32.

Boerhaavia tetrandra Forster.

G. c. Abundant through the island, in many places overgrowing its associates. Leaf blades glabrate, sparingly ciliate, silvery underneath, obtuse to acute, the base truncate to subcordate, average size 2 by 1.0-1.5 cm. (10 by 5-7½ lines). Petioles and stems pubescent. Peduncles sparingly pubescent, stout. Inflorescence umbellate. Flowers white. Whole plant bright green. Comes very close to the glabrate form found on Jarvis Island (Bergman No. 52). Christophersen No. 37.

Portulaca lutea Solander.

H. c. Abundant throughout the island. Christophersen No. 34.

Portulaca oleracea Linnaeus.

Th. o. Scattered throughout the interior. Christophersen No. 25.

Tribulus cistoides Linnaeus.

Ch-N. o. Scattered throughout the interior, particularly the northern part. Christophersen No. 26.

Euphorbia hirta Linnaeus.

Th. l. On the beach crest at the landing place, west coast. Christophersen No. 35.

Phyllanthus niruri Linnaeus.

Th. 1. On the beach crest at the landing place, west coast. The leaves of these plants are exceedingly small, not exceeding a length of 4 mm. (2 lines), and on an average 3 mm. ($1\frac{1}{2}$ lines) long and 1.5-2 mm. (1 line) wide. This material thus has still smaller leaves than the small leaved forms on Christmas, Fanning, and Washington islands. Christophersen No. 28.

Triumfetta procumbens Forster.

Ch. r. On the exposed sandy beach below the beach crest, west coast. Christophersen No. 29.

Abutilon indicum Sweet.

N. r. On the beach crest, west coast. Christophersen No. 23.

Sida cordifolia Linnaeus.

N. o. Scattered throughout the island. Christophersen No. 36.

Ipomoea campanulata Linnaeus.

Ch-M. 1. Abundant on the beach crest near the landing place, west coast. Christophersen No. 27.

VASCULAR PLANTS, HOWLAND ISLAND

Lepturus repens (Forster) R. Brown.

H. o. Abundant on the beach crest at southeastern end, scattered throughout the interior. Christophersen No. 41.

Boerhaavia tetrandra Forster.

G. c. Abundant throughout the island. Identical with the Baker Island form. The leaf form and size is, however, very variable. Christophersen No. 40.

Portulaca lutea Solander.

H. c. Abundant throughout the island. Christophersen Nos. 43 and 46.

Portulaca sp.

This material comes close to *P. oleracea*, but no definite determination has been ventured. Christophersen No. 44.

Tribulus cistoides Linnaeus.

Ch-N. r. Single bushes scattered throughout the interior. Christophersen No. 45.

Cordia subcordata Lamarck.

M. l. A few groves in the south central part. Christophersen No. 39.

Table 16 shows that the flora of the islands visited by the Whippoorwill Expedition consists of about 60 species and varieties of indigenous and accidentally introduced plants. Of these only 2 species (3 per cent) are common to all the islands. These are *Lepturus repens* and *Boerhaavia tetrandra*. Those common only to the three islands of the wet belt, Palmyra, Washington, and Fanning constitute 7 species (11 per cent): *Polypodium scolopendrium*, *Cocos nucifera* (form on Palmyra), *Fleurya ruderalis*, *Pisonia grandis*, *Lepidium owaihiense*, *Suriana maritima*, and *Tournefortia argentea*. All of these except *Polypodium scolopendrium* and *Fleurya ruderalis* are also found on Christmas Island, which is situated in a transition zone to the dry belt. Finally, 2 species (3 per cent) are common only to the islands of the dry belt, Jarvis, Howland, and Baker, namely, *Portulaca lutea* and *Tribulus cistoides*.

This seems to indicate a high degree of dissimilarity between the islands. But the fact remains that all but 3 species from the islands in the dry belt are also found on one or more of the other islands.

Two species (3 per cent) are found on all 7 islands; 1 species (less than 1 per cent) on 5 islands only; 8 species (13 per cent) on 4 islands only; 10 species (17 per cent) on 3 islands only; 12 species (20 per cent) on 2 islands only; 21 species, 1 variety, 1 form (38 per cent) on 1 island only. The data regarding 4 species are uncertain.

TABLE 16. DISTRIBUTION OF PLANTS (PLANTED SPECIES NOT INCLUDED)

Collectors: B (S. C. Ball, 1922); Br (H. F. Bergman, 1924); Ch (E. Christophersen, 1924); Co (C. M. Cooke, 1913); Cp (H. E. Cooper, 1914); HK (W. B. Herms and H. Kirby, 1924); R (J. F. Rock, 1913); S (T. H. Streets, 1873-74). X indicates that the plant has been observed but not collected. For explanation of other symbols see p. 6.

List of plants	Palmyra	Washington	Fanning	Christmas	Jarvis	Howland	Baker
Polypodiaceae							
Asplenium nidus H and E	S. R.	S. Br. HK.					
Nephrolepis exaltata G		S. Br.					
Polypodium scolopendrium G	S. R.	S. Br. HK.	B. Ch. HK.				
Lycopodiaceae							
Psilotum triquetrum G and E		Br.					
Pandanaceae							
Pandanus pulposus Cooperi M	R.						
Pandanus rockii M	R.	Br.?	Ch.?				
Pandanus tectorius M		Br.					
Naiadaceae							
Potamogeton sp.? HH		Br.					
Gramineae							
Cynodon dactylon H		Br.	HK.				Ch.
Eleusine indica Th		Br.					
Eragrostis amabilis Th		Br.	HK.	Br.			
Eragrostis falcata Th				Br.	Br.		Ch.
Lepturus repens H		Br.	B. HK.	Br.	Br.	Ch.	Ch.
Panicum stenotaphroides H	R.			Br.			Ch.

TABLE 16. DISTRIBUTION OF PLANTS (PLANTED SPECIES NOT INCLUDED) Continued

List of plants	Palmyra	Washington	Fanning	Christmas	Jarvis	Howland	Baker
Cyperaceae							
<i>Cyperus pennatus</i> G		Br. HK.					
<i>Cyperus polystachyus</i> G		Br.					
<i>Fimbristylis spathacea</i> H		Br.	B. Ch. HK.				
<i>Fimbristylis pycnocephala</i> H							Ch.
<i>Scirpus riparius</i> G		S. Br.					
Palmae							
<i>Cocos nucifera</i> MM		Br. X.	B. X.	Br. X.			
<i>Cocos nucifera</i> f. <i>palmyrensis</i> MM	R.						
Araceae							
<i>Cyrtosperma chamissonis</i> G		Br. HK.					
Urticaceae							
<i>Fleurya ruderalis</i> Th	R.	Br.	B. Ch. HK.				
<i>Pipturus velutinus</i> N		Br.					
Amaranthaceae							
<i>Amaranthus viridis</i> Th		Br.					
Nyctaginaceae							
<i>Boerhaavia hirsuta</i> G				S. Br.			
<i>Boerhaavia tetrandra</i> G	R.	Br.	B. HK.	Br.	Br.	Ch.	Ch.
<i>Pisonia grandis</i> M-MM	R. Cp.	Br.	HK.	Br.			
Aizoaceae							
<i>Sesuvium portulacastrum</i> Ch			HK.	S. Br.			
Portulacaceae							
<i>Portulaca lutea</i> H			Ch. HK.	Br.	Br.	Ch.	Ch.
<i>Portulaca oleracea</i> Th	R.					Ch.?	Ch.

TABLE 16. DISTRIBUTION OF PLANTS (PLANTED SPECIES NOT INCLUDED) Continued

List of plants	Palmyra	Washington	Fanning	Christmas	Jarvis	Howland	Baker
Lauraceae <i>Cassytha filiformis</i> E		Br.	HK.	Br.			
Cruciferae <i>Lepidium owaihiense</i> Ch	S. R.	S. Br.	Ch. HK.	Ch.			
Leguminosae <i>Canavalia microcarpa</i> Ch-M		S. Br. HK.					
<i>Cassia occidentalis</i> H			HK.				
<i>Desmodium triflorum</i> Ch			HK.				
Zygophyllaceae <i>Tribulus cistoides</i> Ch-N				S. Ch.	Br.	Ch.	Ch.
Simarubaceae <i>Suriana maritima</i> N	S.	S.	S.	S. Br.			
Euphorbiaceae <i>Euphorbia hirta</i> Th		Br. HK.	B. HK.	Br.			Ch.
<i>Euphorbia prostrata</i> Th			HK.				
<i>Phyllanthus niruri</i> Th		Br. HK.	B. HK.	Br.			Ch.
Tiliaceae <i>Triumfetta procumbens</i> Ch			B. HK.				Ch.
Malvaceae <i>Abutilon indicum</i> N					Br.		Ch.
<i>Malvastrum coromandelianum</i> Th and Ch		Br.	HK.				
<i>Sida cordifolia</i> N				Br.			Ch.
<i>Sida fallax</i> N			B. HK.	S. Br.	Br.		
<i>Sida rhombifolia</i> N		Br. HK.		Br.			

TABLE 16. DISTRIBUTION OF PLANTS (PLANTED SPECIES NOT INCLUDED) Continued

List of plants	Palmyra	Washington	Fanning	Christmas	Jarvis	Howland	Baker
Apocynaceae							
Ochrosia oppositifolia M	R. Co.						
Convolvulaceae							
Ipomoea pes-caprae Ch		Br. HK.					
Ipomoea campanulata Ch-M							Ch.
Ipomoea glaberrima Ch-M	R.		HK.				
Boraginaceae							
Cordia subcordata M		Br.	B.			Ch.	
Heliotropium anomalum Ch			B. Ch. HK.	S. Br.			
Tournefortia argentea M-(MM)	R.	Br. HK.	B. HK.	Br.			
Rubiaceae							
Coprosma tahitensis N				Br.			
Goodeniaceae							
Scaevola frutescens N-M		Br.	B. HK.	S. Br.			
Compositae							
Erigeron albidus Th			HK.				
Sonchus oleraceus Th			B.?				
Synedrella nodiflora Th		HK.	B. HK.				
Vernonia cinerea Th		Br. HK.	B. HK.	Br.			

SOURCE OF THE FLORA

NATIVE SPECIES

Of the 60 species and varieties of plants listed in Table 16, about 39 may be considered native; that is, species that have reached the group through natural agencies, wind, water, and migratory birds. Their probable method of transport is shown in the following list adapted in part from Merrill (20):

Asplenium nidus; wind.	Sesuvium portulacastrum; water.
Nephrolepis exaltata; wind.	Portulaca lutea; birds?; water?.
Polypodium scolopendrium; wind.	Portulaca oleracea; birds?; water?.
Psilotum triquetrum; wind.	Cassytha filiformis; water.
Pandanus pulposus var. Cooperi; water.	Lepidium owaihiense; birds?; water?.
Pandanus Rockii; water.	Canavalia microcarpa; water.
Pandanus tectorius; water.	Suriana maritima; water.
Potamogeton sp.?; birds.	Triumfetta procumbens; water.
Eragrostis falcata; water.	?Sida cordifolia; birds?; water?.
Lepturus repens; water.	?Sida fallax; birds?; water?.
Panicum stenotaphroides; water.	Ochrosia oppositifolia; water.
Cyperus polystachyus; birds?; water?.	Ipomoea pes-caprae; water.
?Fimbristylis pycnophala; birds?; water?.	Ipomoea campanulata; water.
Scirpus riparius; birds?; water?.	Ipomoea glaberrima; water.
Cocos nucifera; water.	?Cordia subcordata; water?.
Cocos nucifera f. palmyrensis; water.	Heliotropium anomalum; birds?; water?.
Pipturus velutinus; birds?; water?.	Tournefortia argentea; birds?; water?.
Boerhaavia hirsuta; birds?; water?.	Kadua (Gouldia?) romanzoffiensis; birds?;
Boerhaavia tetrandra; birds?; water?.	water?.
Pisonia grandis; birds.	Scaevola frutescens; water.

The species *Sida cordifolia* and *S. fallax* may have been accidentally introduced, as was undoubtedly *S. rhombifolia*; and *Cordia subcordata* may have been introduced by the ancient Polynesians, as suggested by Hillebrand (15).

INTRODUCED PLANTS

Some of the more common species obviously introduced for planting on Christmas, Washington, and Fanning islands are given in the following list. They are not included in Table 16. C, Christmas Island; F, Fanning Island; W, Washington Island.

Acalypha wilkesiana (F).	Ficus sp. (F).
Anona squamosa (W, Bergman No. 96).	Hibiscus rosa sinensis (F, W).
Araucaria sp. (F).	Hibiscus tiliaceus (C).
Artocarpus incisa (F, W).	Mangifera indica (F).
Calophyllum inophyllum (F).	Morinda citrifolia (F, W, Ball No. 4,
Capsicum annuum (W).	Bergman No. 100).
Carica papaya (F, W).	Musa sapientum (F, W).
Casuarina equisetifolia (F).	Pandanus tectorius (C, Bergman No. 32).
Clerodendron inerme (W).	Plumiera acutifolia (W).
Erythrina indica (C).	Psidium guajava (F, W, Bergman No. 92).

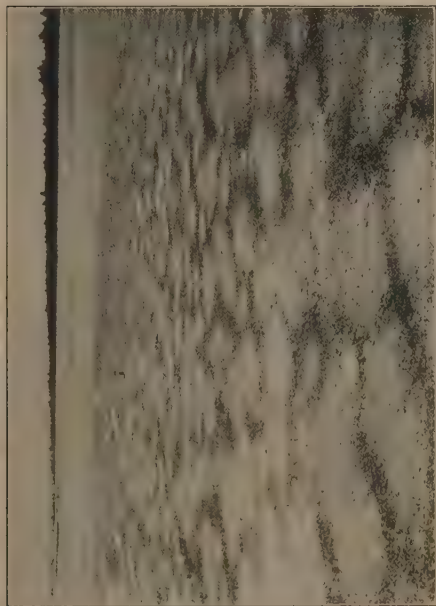
Cyrtosperma chamissonis was originally planted, but now grows in a natural state on Washington Island.

About 20 species, most of them widely distributed weeds, have been accidentally introduced by man. Those which have been recorded are given in the following list adapted in part from Merrill (20).

Cynodon dactylon	Euphorbia hirta
Eleusine indica	Euphorbia prostrata
Eragrostis amabilis	Phyllanthus niruri
Cyperus pennatus	Abutilon indicum
Fimbristylis spathacea	Malvastrum coromandelianum
Fleurya ruderalis	Sida rhombifolia
Amaranthus viridis	Erigeron albidus
Cassia occidentalis	Sonchus oleraceus
Desmodium triflorum	Synedrella nodiflora
Tribulus cistoides	Vernonia cinerea

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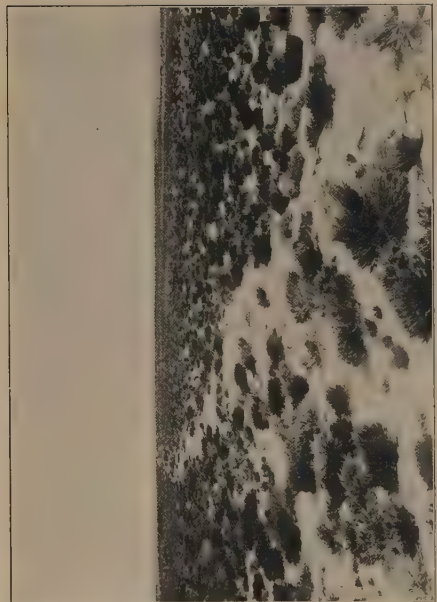
A



B

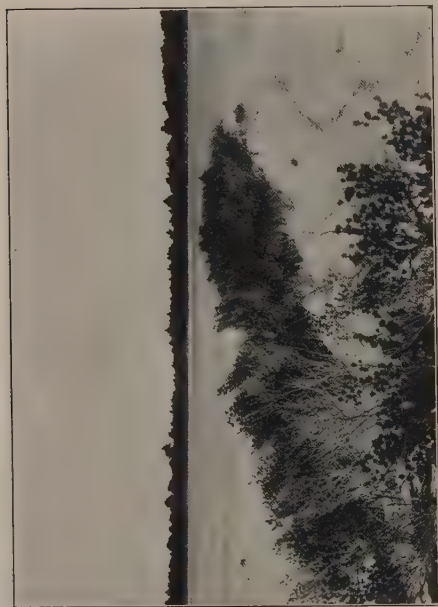


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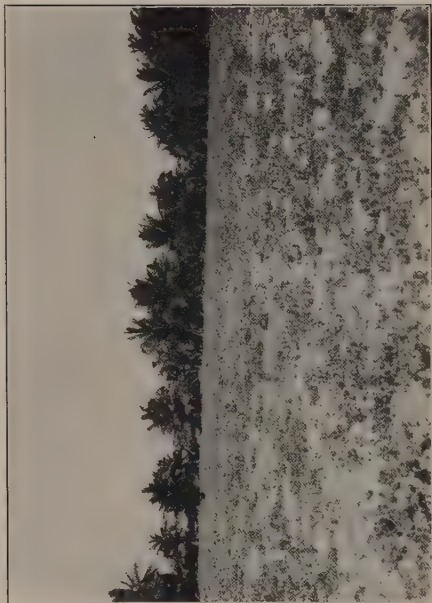


D

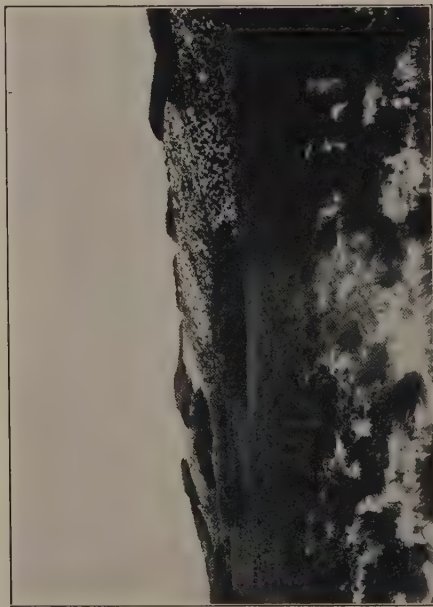
VEGETATION ON CHRISTMAS ISLAND: A, POLYGON FIELD ON FORMER LAGOON SITE; B, SIDA FALLAX-TOURNEFORTIA ARCENTEA FOREST, NORTH OF LONDON; C, PORTULACA, LUTEA-SIDA FALLAX SCRUB, NEAR POLOGNE; D, HELIOTROPITUM ANOMALUM-KADUA ROMANZOFFIENSIS SCRUB, SOUTHEASTERN PENINSULA.



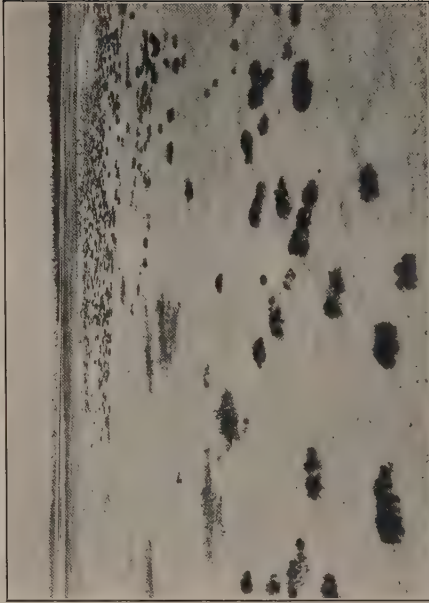
A



B



C

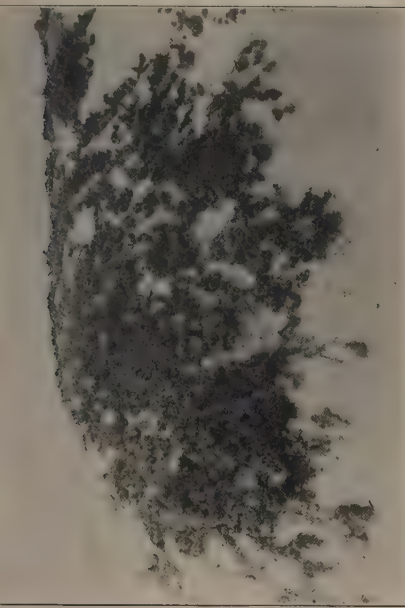


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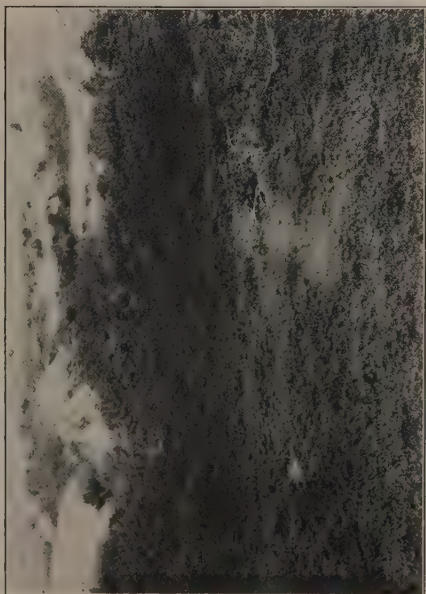
VEGETATION ON CHRISTMAS ISLAND: A, *SURIANA MARITIMA* SCRUB ON SAND SPIT IN LAGOON; B, *HELIOTROPIMUM ANOMALUM* DWARF SCRUB; C, *LEPTURUS REPENS* AND *HELIOTROPIMUM ANOMALUM* ON DUNES, *SCAEVOLA FRUTESCENS* IN BACKGROUND, EAST COAST; D, *ERAGROSTIS FALCATA* AND *SESUVIUM PORTULACASTRUM* (MIDDLE LEFT) ON SAND FLATS NEAR LAGOON.



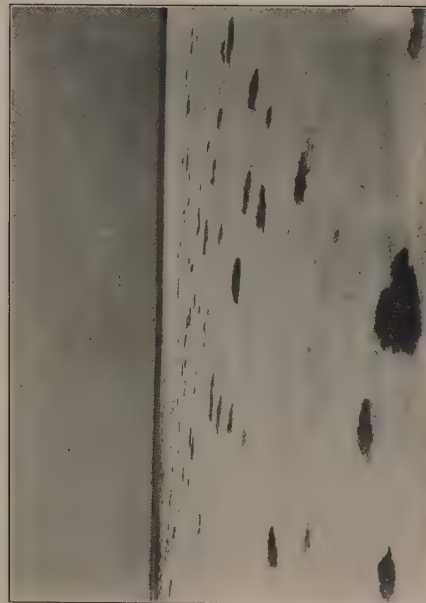
A



B



C



D

VEGETATION ON CHRISTMAS AND JARVIS ISLANDS: A, *LEPTURUS REPENS* CREEPING HABIT (FOREGROUND), THE MORE COMMON TUFTED HABIT (BACKGROUND), LAGOON BEACH, CHRISTMAS ISLAND; B, *HELIOTROPIMUM ANOMALUM* AS SAND BINDER, ON DUNES NORTHWESTERN COAST, CHRISTMAS ISLAND; C, *SESUVIUM PORTULACASTRUM* AND *BOERHAAVIA TETRANDEA* IN THE CENTRAL DEPRESSION, JARVIS ISLAND; D, SCATTERED GROWTH OF *SESUVIUM PORTULACASTRUM* NEAR THE RELIC LAGOON, JARVIS ISLAND.



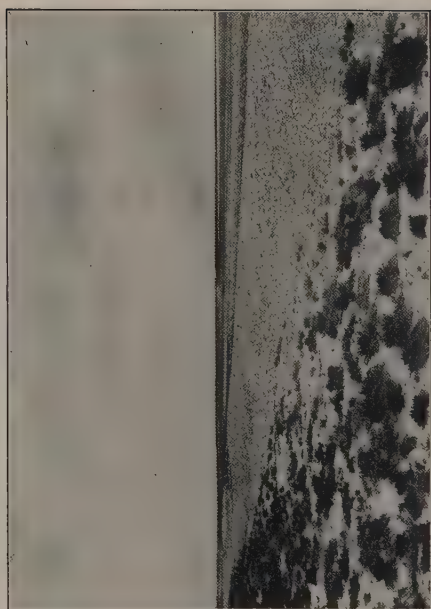
A



B



C



D

VEGETATION ON JARVIS ISLAND: A, SESUVIUM PORTULACASTRUM GROWING ON DEAD BUNCHES OF LEPTURUS REPENS NEAR THE RELIC LAGOON; B, FOSSIL BEACH LINE THROUGH GROWTH OF LEPTURUS REPENS, EAST COAST; C, PORTULACA LUTEA ASSOCIATION ON LEE SLOPE OF BEACH CREST, EAST COAST; D, FOSSIL BEACH.



A



B



C

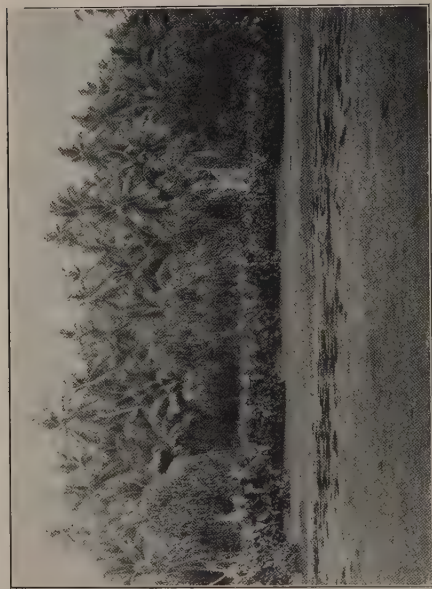


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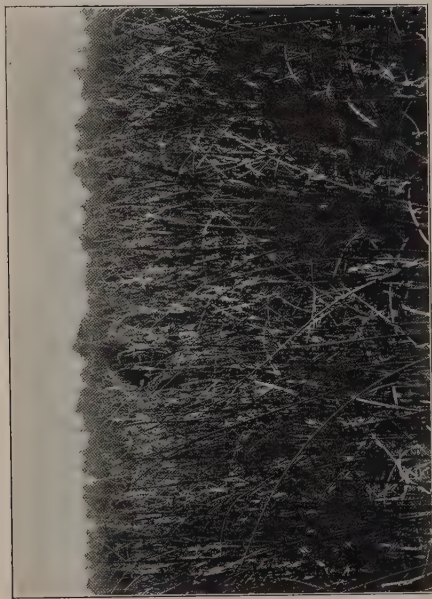
VEGETATION ON FANNING, WASHINGTON, AND JARVIS ISLANDS : *A*, PANDANUS, FANNING ISLAND; *B*, ASPLENium NIDUS-COCOS NUCIFERA FOREST, WASHINGTON ISLAND; *C*, VIGOROUS BOERHAAVIA TETRANDBRA ON LEE SLOPE OF BEACH CREST, EAST COAST, JARVIS ISLAND; *D*, TOURNEFORTIA ARGENTEA FOREST ON BEACH CREST.

LEPTURUS REPENS IN THE FOREGROUND, SOUTH COAST, WASHINGTON ISLAND.

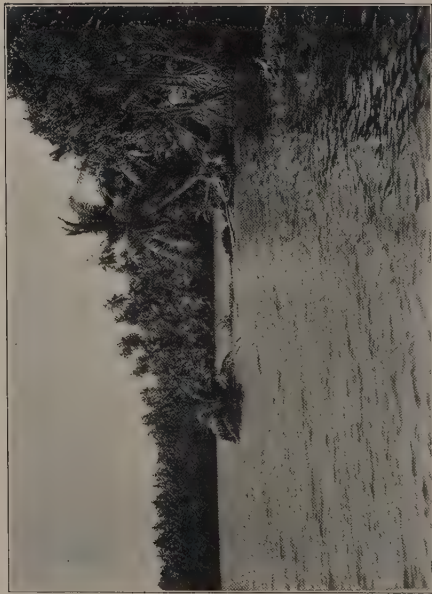
(PHOTOGRAPHS *A* AND *B* BY C. K. WENTWORTH)



A



B



C



D

PEAT BOG, WASHINGTON ISLAND: *A*, *CYRTOSPERMA CHAMISSONIS*, *PANDANUS* SP. AND *COCOS NUCIFERA* AT EDGE OF BOG; *B*, *SCIRPUS RIPARIUS* IN THE WESTERN BOG; *C*, FRODING SHORES OF THE FRESH WATER LAKE; *D*, EDGE OF BOG, WITH *SCIRPUS RIPARIUS* (LEFT), *POLYPODIUM SCOLOPOENDRIUM* (CENTER), *CYRTOSPERMA CHAMISSONIS*, *PANDANUS* SP., AND *COCOS NUCIFERA* (RIGHT). (PHOTOGRAPHS BY C. K. WENTWORTH.)



A



B



C

VEGETATION ON BAKER AND HOWLAND ISLANDS: *A*, *LEPTURUS REPENS*, *PORTULACA LUTEA*, AND *BOERHAAVIA TETRANDRA*, BAKER ISLAND; *B*, GROVE OF *CORDIA SUBCORDATA*, HOWLAND ISLAND; *C*, *LEPTURUS REPENS* ON SHIFTING SAND ON BEACH CREST, SOUTHEASTERN COAST, HOWLAND ISLAND.

(PHOTOGRAPHS BY E. L. CAUM)

